Rapid Resource Assessment for Rural Electrification:

Development and Demonstrating A Methodology

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ACRONYMS

ESCO	Energy Service Company
GIS	Geographic Information Systems
GRZ	Government of the Republic of Zambia
ICT	Information and Communication Technology
ISIC	International Standard Industrial Classification
JICA	Japan International Cooperation Agency
K	Kwacha
Km	kilometer
Kv	kilovolt
kW	Kilowatt
kWh	Kilowatt hour
kWp	Kilowatt peak
m/s	Meters per second
MEWD	Ministry of Energy and Water Development
MOE	Ministry of Education
MOH	Ministry of Health
mW	Megawatt
NGO	Non-governmental organization
NORAD	
NREL	National Renewable Energy Laboratory
PV	Photovoltaic
RE	Renewable Energy
REA	Rural Electrification Authority
RES	Rural Energy Services
RRA	Rapid Resource Assessment
SHS	Solar Home System
SIDA	Swedish International Development Agency
UNIDO	United Nations Industrial Development Organization
WWF	World Wildlife Foundation
ZESCO	Zambia Electric Supply Company

1. Rapid Resource Assessment for Rural Electrification

1.1. Introduction

It is hard to imagine that in a country with abundant resources and needs to match that less than two percent of Zambia's rural population has access to electricity. Traditional grid based expansion programs have so far failed to produce significant inroads and, in response, the Government of Zambia created the Rural Electrification Authority (REA) to implement innovative approaches to rural electrification and oversee the Rural Electricity Fund (REF).

USAID, in a continuing effort to bring pivotal assistance to Zambia's electricity sector, funded assistance to the REA for the preparation of a methodology for Rapid Resource Assessment (RRA) as an innovative substitute for the traditional rural electrification master plan and, if possible, to apply that methodology to one or two examples. Rural electrification master plans are usually expensive and time consuming to produce, both of which present problems to a resource constrained government that needs to act quickly to invigorate its rural economy.

The purpose of this task is to develop a methodology for RRA and to provide REA with tools for identifying and prioritizing rural electrification projects. In so doing, the methodology will also demonstrate a strategy for selecting and funding projects. The goal is to jump start the process of rural electrification in the most effective manner. This was to be the first part of a two step process agreed upon between USAID and SIDA. USAID would fund the development and demonstration of the methodology and SIDA would fund the wide scale implementation.

The development of a comprehensive rural electrification plan for Zambia will be based on a series of discrete steps which will build, from the bottom up and from the national planning perspective, a set of supply and demand tools that can be used to guide development funds toward the projects with the greatest likelihoods of success in the near term. This effort will complement activities at the policy level in Zambia to fund and empower the REA. Non-grid approaches to rural electrification are expected to be undertaken to a great extent by non-governmental entities, including, cooperatives, energy service companies, and other organizations.

In order for non-grid approaches to rural electrification to succeed, it will be necessary to identify potential areas where there is sufficient density of demand, actual or potential, combined with the possibility to supply at least some electricity from local primary energy sources. The actual examples of the RRA method combine these demand side and supply side elements.

1.2. What is Rapid Resource Assessment

Rapid Resource Assessment is a newly emerging methodology with origins in rapid rural appraisal. Rapid rural appraisal is often described as a process of learning about rural conditions in an intensive, iterative, and expeditious manner or any systematic activity designed to draw inferences, conclusions, hypotheses or assessments, including the acquisition of new information during a limited period of time. An efficient RRA involves participation of small multidisciplinary teams that employ a range of methodological tools and techniques specifically selected to facilitate understanding of rural conditions in their natural context. RRA allows the user to obtain relevant and accurate information at low cost by rapid cycles of interaction among team members and locally impacted communities and creative utilization of various data collection tools and techniques, such as direct observation, short questionnaire, brief and in-depth interviews. RRA is a very flexible process that allows modification along the process, where appropriate.

RRA activities fall into three broad categories:

- Preparatory work that includes selection of a multidisciplinary team, background information retrieval by maximal utilization of pre-existing data, team discussion for developing preliminary hypotheses, and selection of research tools and techniques;
- Short single or multiple field visits to the study areas;
- Discussion and analysis of the findings among the team members and often the local community, aiming at reaching a consensus on what has been learned and what is still unclear. The writing should also take place immediately following fieldwork as any delay may result in loss of valuable information and insight.

The RRA process cannot be replicated exactly by a single model in different countries. The economies as well as various other circumstances in the countries are different. Therefore it is very difficult to establish a fixed pattern. However, there are some common principles to implementing such methodologies and ensure generating of reliable information. These fundamental principles are as follows:

1. Using triangulation during data gathering, which means using more than one (often three) source of information for validation;
2. There is always a certain level of “optimal ignorance”, which means establishing the borders and limits to data collection in order to avoid spending significant time and effort on gathering information that brings little added value;
3. Appropriate imprecision;
4. Rapid and progressive learning;
5. Learning from, and along with, rural people.

Data gathering includes primary and secondary data collection. Primary data collection varies significantly depending on the subject of RRA. In the case of energy resource assessment, primary sources would include direct observations, actual meter readings, key informants, and interviews.

Secondary sources of data collection include review papers on the issue for the particular region under study; published government data and statistics; discussion with selected experts from various organizations; informal discussions with selected key experts; maps and aerial photographs; and knowledge of existing programs for rural development, both regional and national.

RRA is not a substitute for comprehensive studies but serves to complement them, especially during the initial stages of research or strategic planning.

1.3. Rapid Rural Appraisal Tools

To construct examples of the RRA and to provide a more general approach and methodology for this type of effort, CORE has worked with two analytical approaches that can greatly assist in the selection of potential development sites by improving the ability of the REA to assess the demand and supply factors that may contribute to success in projects.

1.3.1. Using Geographic Information Systems for Rapid Energy Resource Assessment

Geographic Information Systems (GIS) are quickly becoming an everyday tool in peoples' lives. They can be used for a variety of applications, ranging from domestic interactive maps and vehicle GPRS to system planning. In the energy field, GIS is often used for planning and designing city power lines, and for planning installation of energy efficient technologies. One of the most widespread GIS tools is the ArcView application, used by various organizations to build their specific GIS systems. For the purpose of this project, the team utilized a publicly available system that could be used by all energy sector stakeholders without making additional investments into software purchases- DIVA-GIS. DIVA was designed for environmental and biological spatial analysis, but is also very convenient for energy resource analysis.

GIS are a form of digital maps. These maps are layered, with each layer containing a particular feature of the area under investigation. These layers of information can provide a comprehensive crosscut of a region, including the geographical location of the country and regional borders, rivers, lakes, roads, railroads, towns and villages, as well as the information about the industries, agriculture, environment, energy and other statistical information.

The information is arranged in layers on the map. The user can create a project and include the layers of the data relevant to the task. These layers can be observed individually, or in any combination including altogether, on the map. This provides the possibility of seeing a complete picture of technical, economical, or combined conditions in specific region. The system allows a user to manipulate the data in different ways, grouping them and building distribution patterns for analysis. Figure 1 below illustrates a sample map created for Zambia Rural Electrification RRA:

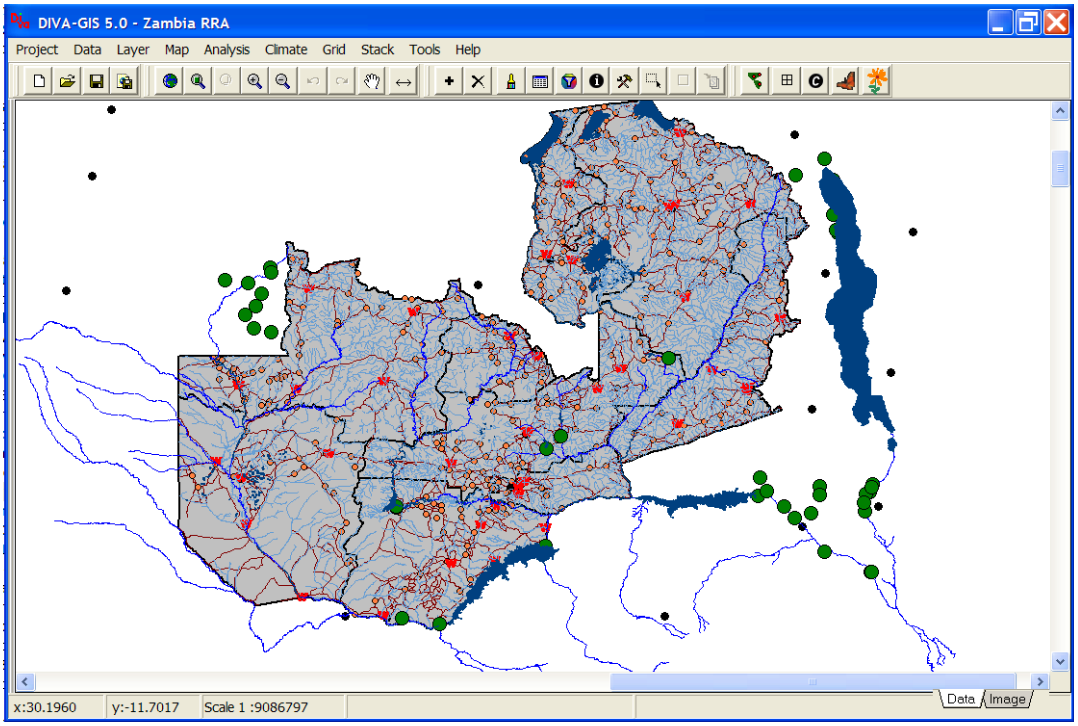


Figure 1 Sample GIS Map of Zambia

(Active information layers represent country and province borders, rivers, lakes, major towns, meteorological stations and power plants.)

DIVA is particularly useful for analyzing the existing infrastructure and available energy resources. By adding successive layers of information, the user can quickly see (determine) which areas have the strongest electricity demand potential. The GIS can answer questions such as: How many potential residential customers are there? What is their income? What types of economic activity exist in the area? Are their other potential users such as schools, clinics or government offices? How far is this area from roads and other transportation? Based on this data, demand can be approximated. In this manner comparisons can be made quickly with other locations to develop a ranking of demand centers.

Likewise, areas can be viewed based on potential electricity supply. Are there renewable resources nearby in economic quantities to supply electricity? What is the stream flow of the nearby river? Is there sufficient solar radiation for solar systems? Are there geothermal resources? How far is the national grid? If correctly populated, GIS can answer a host of supply related questions. This information can be used for further modeling of technical options for electrification based on the location and availability of renewable resources, proximity to the existing grid and other pertinent supply factors. Such distance information facilitates the supply cost estimate.

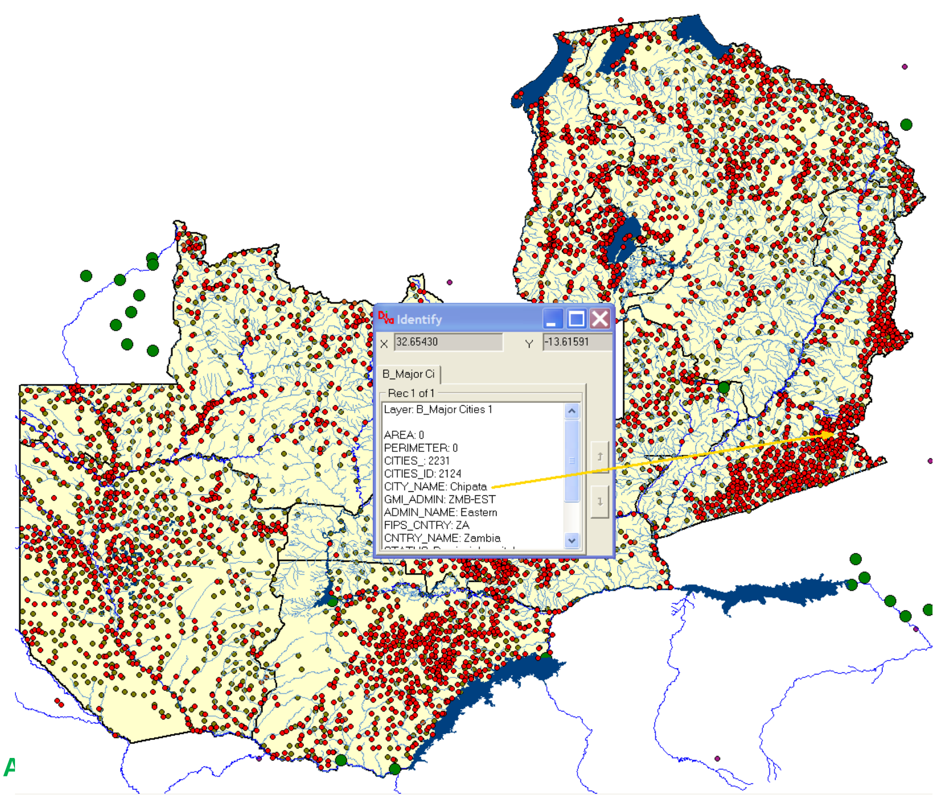
One of the most important things that the use of GIS does is to shift rural electrification away from its former narrow focus. It now allows the analyst, planner or policy maker to view electrification as part of an integrated rural development system. Planned rural development can be added as a layer. For example, one layer could be a plan for roads or schools or clinics. As a stand-alone project the benefits of a school will certainly be less than when combined with the supply of electricity. In essence, the use of GIS forces the electricity planner to see the bigger picture because he or she must collaborate with other rural development agencies in the collection of potential demand and supply data which, in turn, leads to more integrated rural development.

This GIS is used to convey information on the following key indicators of demand and supply potential:

- Population and Income
- Schools, Clinics and Government Offices
- Distance to Transportation such as Road or Rail
- Rainfall
- Rivers and stream flow
- Wind direction and speed
- Solar radiation
- Geothermal Potential
- Distance to the National Grid
- Crop patterns
- Forest cover
- Industrial and commercial activity

At present, the GIS database shows the locations of schools that lack electricity, a rough proxy for the population currently not served by electricity. Figure 2 below shows the GIS results for locating schools without electric power supply in 2000.

Figure 2 GIS Map of Zambian Schools without Electricity Supply, 2000
(red dots represent schools without electricity)



Overlays on the GIS map can be modified for a large variety of databases, to track social and non-economic characteristics, as well as economic and physical characteristics. Indeed, it is possible to help determine the parts of the country that offer the best promise for indigenous energy generation using these map overlays.

Specific overlays for the rural electrification RRA include the ones that help to identify the following criteria for choosing a location for a rural electrification project:

Criteria on Demand Side:

- Current or near-term potential for development of agro-industrial electricity use – economic & resource overlays;
- Current use of diesel gen-sets in region – comparison of electrification overlay with diesel gen-set map;
- Population density greater than provincial average – population overlay;
- Household income greater than provincial average – income overlay map (in the future);
- Proximity of schools & government health clinics – school and clinic overlays.

Criteria on Supply Side:

- Availability of renewable resources;
- Proximity to roads & rivers – roads and rivers overlays;
- Likelihood of complementary hybrid systems – hydro/diesel, hydro/wind, wind/diesel – wind and river system overlays;
- Proximity to existing grid – comparison of potential demand center to grid map.

To make the most effective use of these overlays, it is necessary to have an initial hypothesis regarding the feasibility of providing electric service to specific towns, villages or locales, which can then serve as a standard against which to compare competing projects. As mentioned above, the GIS maps can assist the analyst in locating those areas that might prove especially promising for new electricity service. The initial hypothesis is based on the demand-side analysis.

Essentially, the demand side analysis indicates whether and to what extent there is, or can be, sufficient electricity demand in a given village or locale to justify investment in a small grid. This grid should be large enough to achieve certain minimal economies of scale in output and should provide for economically beneficial demand for electricity. The hypothesis states that this electricity can be provided using a combination of conventional and local resources at an acceptable price.

1.3.2. An Optimization Model for Energy Resource Assessment

HOMER, a publicly available optimization model for distributed power, is used for determining the cost of supply. HOMER was developed by the U.S. Department of Energy's National Renewable Energy Laboratory (NREL). HOMER simplifies the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications. It offers a wide variety of power system configurations, and their components. HOMER helps to evaluate these configurations from both the technical and economical feasibility points of view. The HOMER model simulates stand alone hydro, wind, solar, and diesel based power systems:

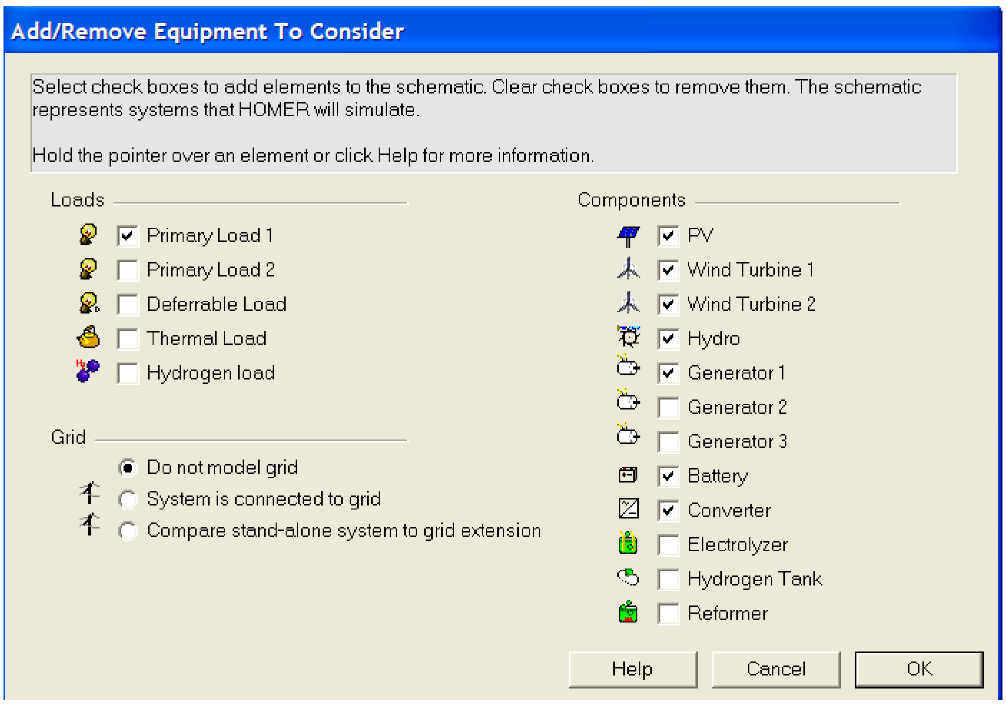


Figure 3 Sample HOMER equipment selection screen

To use HOMER, the model has to be provided with inputs, which describe technology options, component costs, and resource availability. Based on these inputs, the model will simulate different system configurations, or combinations of components, and generate results that can be viewed as a list of feasible configurations sorted by net present cost.

The model analyzes the impact of changes in factors such as resource availability and economic conditions on the cost-effectiveness of different system configurations, by performing sensitivity analyses. Such sensitivity analysis can answer general questions about technology options and facilitate planning and policy decisions.

HOMER simulates the operation of a system by making energy balance calculations for each of the 8,760 hours in a year. For each hour, HOMER compares the electric and thermal demand in the hour to the energy that the system can supply in that hour, and calculates the flows of energy to and from each component of the system. For systems that include batteries or fuel-powered generators, HOMER also decides for each hour how to operate the generators and whether to charge or discharge the batteries.

HOMER performs these energy balance calculations for each system configuration that you want to consider. It then determines whether a configuration is feasible, i.e., whether it can meet the electric demand under the conditions that you specify, and estimates the cost of installing and operating the system over the lifetime of the project. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel, and interest.

In order to test the hypothesis a way must be found to compare a given service area proposal to other proposals for other service areas. The way that we have found to make such comparisons is to use a village electricity model to compare the key performance and cost parameters for a variety of investment options.

Homer is intended to provide a rapid screening of potential technologies to match the demand and local energy supply characteristics of a chosen demand center at least cost. Key characteristics of an energy system that are included in the Homer modeling approach include the following:

- Load curve – at whatever level of detail exists for the system;
- Resource supply curves for wind, water and sun;
- Reliability requirements for system;
- Hybrid system preferences – multiple sources, including diesel backup or primary diesel generation;
- Fuel prices;
- Interest rates;
- Replacement and service costs for various technologies;
- Electricity storage and management.

Based on the inputs to the Homer model, the user can derive a wide array of potential results, including:

- Cost of generation
- Initial investment costs
- Present value of total costs
- Renewable energy fraction for different system choices

Of great interest and usefulness is the ability of Homer to provide side-by-side comparisons of the key characteristics of the least cost set of systems. Homer is able to provide analytical assistance on many of the important economic and quantitative issues that must accompany an appropriate rapid assessment methodology. These economic criteria include:

- Ability of economic activity in target region to generate payments for electricity;
- Existence of market infrastructure to absorb additional economic activity including:
    - Roads, water transport etc.
    - Value-added activities – schools, health clinics, communications;
- Repair & parts infrastructure to maintain system;
- Organization to collect fees & operate system;
- Potential contributions to electricity output from local or renewable resources.

The Homer output can also be used to compare alternative projects that are candidates for government or foreign funding. In this era of measurable performance metrics, a method of comparing the probable output of alternative uses of government or other funds is a must.

1.4. Rapid Resource Assessment Methodology

The RRA takes place in three steps, of which the first two steps are concurrent. In the first step, potential demand areas are assessed and ranked. In the second step, potential areas of supply are assessed and ranked. The third step matches demand with supply and determines an overall priority ranking of projects.

There are several basic postulates upon which the RRA methodology is based, which the REA should follow in developing its overall rural electrification strategy.

- Most rural households cannot fully support a rural electricity project. This means that either the quantity they consume or their ability to pay or both is below that required for an economic rate of return.

The average rural household monthly income was estimated to be 283,796 kwatcha (K). However, this must be viewed with caution for at least three reasons: (1) people tend to less accurately report their income than expenditures, (2) 48% of this was imputed income from consumption of own agricultural produce and this may not reflect market prices for the self consumed goods, and (3) people will tend to underreport or not report at all begging or borrowing. Expenditures are a more reliable indicator.

Table 1 presents monthly expenditure data for 2002-2003. Mean rural household expenditures including self produced food totaled 386,676K per month. Since the bulk of rural peoples are at or below the poverty level, the expenditures devoted to food are not discretionary. In other words, at the subsistence level they are highly unlikely to divert spending from food to nonfood items and some portion of additional income is likely to go to food. Approximately 18% of total expenditures or 70,596K was spent on non-food items per month and mean monthly expenditures on household utilities including energy was 3,530K. Rural households consistently spend 5% of their monthly non-food expenditures on household utilities with the exception of large farmers.

Table 1 Monthly Expenditures by Household Type in Kwacha, 2002-2003

Consumer	Total Expenditure	Nonfood Expenditure	Expenditure on Utilities	Percent Nonfood to Total Expenditures	Utilities as % of Nonfood Expenditure
All Zambia	490,530	115,536	6,932	24%	6%
Rural	386,676	70,596	3,530	18%	5%
Small Scale Farmer	377,001	65,016	3,251	17%	5%
Medium Scale Farmer	759,491	213,443	10,672	28%	5%
Large Scale Farmer	1,869,494	786,572	110,120	42%	14%
Non-Ag Household	286,862	122,322	6,116	43%	5%

Utilities represent items such as water, energy, and phone service. To put this in perspective, if we assume that the average rural household spent all of its utility budget on electricity at 207 kwacha per kwh, this family could consume slightly more than 17 kwh per month or enough to power 2 sixty watt light bulbs for a little less than 5 hours per day. However, it is unlikely that the typical rural family could spend all of its utility expenditures on lighting. Table 6 shows the principal energy sources for lighting and cooking in rural areas.

Only 3% of rural households use electricity for lighting, with paraffin and kerosene as the main sources of lighting, accounting for 63 percent of rural households' main lighting energy source. Other surveys indicate that the bulk is actually paraffin. Note that the main source of cooking fuel, 88% for rural households, is from self collected fire wood from which there is no monetary outlay. This information is valuable because it tells us how much of a rural household’s money income is devoted to energy. Clearly, for many families on the lower end of the income spectrum, the vast majority of energy services are self supplied – that is through the gathering of fuel wood, crop residues, and other biomass. Energy expenditures were dominated by wood, charcoal, paraffin and candles. Wood and charcoal are used mainly for cooking and heating, while paraffin and candles are the main source of lighting.

It is important to note that the above discussion assumes that people can move from their current energy source to electricity without any conversion costs. Conversion costs include the cost of installation or hookup and also the cost of new appliances for electricity. For example, a home switching to electricity would need to purchase wiring and meters as well as light bulbs. Empirical evidence from the developing world clearly indicates that households transition to different forms of energy based on complex economic, cultural, technical and social relationships. People do not just go from cooking on firewood to cooking on electricity. Additionally, if they used a certain amount of lumens or btus in, for example, lighting, they do not use the same amount when moving up from candles to kerosene or from kerosene to electricity.

These findings lead to several major conclusions that have profound implications for rural electrification.

- First, given these income levels, some electricity services will need to be subsidized. As shown above, if rural households were putting all their utility expenditures on lighting, this would mean consumption of 17 kWh per month or enough to run two 60 W electric light bulbs for about 5 hours per day.

- Second, residential energy use will be very limited and there is a definite transitioning in energy use that takes place. The order of use will most likely be lighting, radio, fan, TV, and then an iron or some other small appliance. It will be a long time before electricity takes on uses for cooking and heating. This means that, until incomes rise significantly, only a small portion of energy expenditures will be directed to electricity. **Residential consumers will consume very small amounts of electricity for the foreseeable future.**

- Third, another problem exists because of such low income levels and imperfect markets. Even if consumers were willing and able to afford the full cost electricity per kilowatt hour, they certainly could not afford the connection costs. This is called the first cost problem. For example, it has been estimated that the cost of purchasing a small solar home system would be 61% of a typical Zambian households annual income.[1] In essence, it means that even if consumers would benefit or save money by paying their monthly electricity bill, they could not afford the "first cost" of opting in to electricity consumption. With rural Zambians spending 82% of their income on food, they would be unable without some form of subsidy to purchase a SHS. This leads many countries to subsidize connection costs even if they do not subsidize consumption or to provide other forms of concessional financing.

- Fourth, even when the first cost problem is overcome, the low population density coupled with the low income and low demand, will mean that either: (a) the consumption will need to be met by small modular units like solar; or (b) that a base load needs to be identified and developed such as a school or clinic or a larger scale economic use such as milling or irrigation.

- Together, these first four conclusions lead to a fifth and sixth conclusion that will have profound implications for the implementation of rural electrification in Zambia.

- Fifth, where incomes and consumption are unlikely to support electricity, then rural electrification may need to focus on finding or creating a customer that can act as the base load as well as subsidize the other users[2]. Then, productive

[1] Renewable Energy Strategies for Rural Africa, AFREPREN.
[2] This subsidization can be indirect in that the increase consumption allows economies of scale in supply and lower costs. For example, the project sponsor identifies the use of electricity for a grain mill and then uses mini hydro instead of solar. This will result in lower costs of production for all users. The

uses of electricity that will reduce costs, increase incomes or both. This must be the cornerstone for most rural electrification activities. It also means that this productive use will subsidize other consumers. Productive use here can be defined as either income generating activities such as milling or irrigation or end use in clinics or schools.

- There is an important difference between these two types of productive uses. In the first case, the productive uses are those that have economic impacts in the near term and those act to increase consumption and ability to pay because the demand for electricity grows as income increases. This first case impacts rural electrification in two ways. First, it acts as a base load with the consequent reductions in the cost of supply. Second, in the near term it increases economic activity in the area and increases demand due to the positive spillover effects. In the second case, those that consume education and health services will see an economic impact but it is usually in the distant future. The second use can benefit rural electrification by acting as a base load and reducing costs in that manner. The danger herein for the project sponsor is the payment record of the Ministry of Education and Health for such services.

- Sixth, in the case of income generating activities, subsidization will be required in almost all cases because of the first cost problem. For example, farmers will undoubtedly benefit from using electricity to irrigate their lands. Recent studies show an increase in farm incomes between 600% and 800% from the introduction of small hand-pumps on rural farms in Zambia. However, with the pump costs of US $90, farmers could not afford to purchase the pumps without some form of credit that takes into account the timing between planting, harvesting and sale and the precarious financial condition of subsistence farmers. Low cost credit schemes will also be needed for many productive uses.

The following steps are recommended in conducting the RRA in Zambia:

1. Identify major organizations and individual experts in Zambia involved in rural electrification or that could potentially be involved.
2. Develop a plan of interviews and meetings
3. Gather and assess all pertinent supply side data, including GIS information, on renewable energy sources:

Hydro Resources:

- Existing measurements of the rivers flow rates in throughout the country;
- Rainfall data so that the rainfall approximation method can be used to estimate the flow rates of the rivers in identified demand centers, where the river flow data is not available;
- Existing studies that have been conducted on mini/micro hydro locations;
- Identify data gaps and the measurements that need to be performed.

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subsidization can be direct when the base load use pays more than its marginal supply costs, thereby lowering the amount needed to be covered from other users.

Solar resources:

- Existing measurements (sunshine hours);
- Existing studies that have been conducted on mini/micro hydro locations;
- Identify data gaps and the measurements that need to be performed.

Wind resources:

- Existing measurements (wind speeds);
- Existing studies that have been conducted on wind power applications in Zambia;
- Location of existing stations and their applicability for representative wind measurements;
- Identify data gaps and the measurements that need to be performed.

Biomass Resources:

- Collect data on agriculture and forest wastes and based on the conversion ratios estimate the amount of biomass available for electricity generation;
- Existing studies that have been conducted on biomass projects in Zambia;
- Identify data gaps.

Geothermal resources:

- Collect data on different spring sites in Zambia;
- Assess the geothermal potential for electricity generation.

4. Collect information, including maps and GIS data on the location of existing power transmission lines, as well as power plants and substations;

5. Collect the available demand data, including:
    - Census data;
    - List of industries, their locations and parameters, energy demand;
    - List of agricultural farms, their locations and parameters, energy demand;
    - Locations and population of the towns and villages;
    - Location and energy needs of the schools;
    - Location and energy needs of the hospitals.

5. Enter all GIS information into DIVA-GIS, and create various maps to analyze the regional availability of electric power in Zambia;

6. Analyze all energy resource data and rank the demand centers located in the vicinity of the available energy resources;

7. Use the hydro, solar and wind data in the HOMER optimization model to identify feasible technological solutions for off grid rural electrification;

8. Assess the demand centers based on their economical development potential, importance for Zambian economy, population income levels and ability to pay for electricity;

9. Match the results of the resource assessment and demand assessment, and identify priority areas for rural energy projects implementation. The economic factors and usage of energy for productive purposes should prevail when determining the development priorities. The individual potential projects should be considered in the context of the country wide rural energy development policy, national power grid development plan, and financial feasibility based on the ability of the population to pay for the electricity produced, or availability of governmental subsidies or donor grants or loans. It is important to use a complex approach to utilization of energy resources in the rural areas. For example, in many areas hydro power can be used to both produce electricity and as mechanical force to run grain mills. In the areas with a steady but slow wind speed, instead of using a wind turbine, this wind can be used to drive a water pump for irrigation purposes.

1.4.1. Data Collection and Review

The Project Team undertook an aggressive approach to gathering the data for the initial Rapid Resource Assessment. The team developed a comprehensive list of organizations and individual experts in Zambia involved either in various aspects of rural development or general research activities that may produce relevant information. The objective was to collect available data both on energy resource supply and demand, as well as the information about existing or planned rural development or rural electrification projects. The data gathering approach included e-mail and telephone communication, visits to the data source organizations, interviews with the Government officials and industry experts, analysis of previous reports related to rural development in Zambia, and an internet search for publicly available statistics, energy data, and GIS data. The site visits to observe living conditions of the rural population, and existing energy production were also a part of the data collection mission. As a result, a large amount of the data was collected. The project mission also identified the gaps in the available data, and identified the potential sources and/or methods to collect this missing information.

The table below illustrates the sources and availability of specific data categories.

Table 2 Data categories for the RRA and the potential sources of the data.

Data Category	Source of Data	Status of Data
Wind data	Meteorological department of Zambia	Collected: Table/GIS
Geothermal resource	Geological Survey of Zambia	Need to collect
Mini/micro hydro assessments	ZESCO, Donor Agencies: SIDA, UNIDO, NORAD, UN, USAID, JICA	Partially collected
Rainfall data	Meteorological department of Zambia	Collected: Table/GIS
Existing/Planned Rural Electrification	Electricity Regulatory Board (ERB), ZESCO,	Partially collected

Projects	Private ESCOs, Rural Electrification Authority (REA)	
Existing Industry	Ministry of Commerce	Collected
Solar Resource Data	SIDA, University of Zambia: (Dr. Geoffery Munyeme)	Insufficient -- Need to collect
Wind Technologies	University of Zambia (TDAU) - Dr. M.J. Tamba Tamba	Partially collected
River Streamflow Data	Ministry of Energy and Water Development -- Hydro Unit	Collected: Table/GIS, may require additional details for specific site locations
Census Data	Central Statistic Office (CSO)	Collected
Schools Data	Ministry of Education	Collected
Hospitals Data	Ministry of Health	Need to collect
Agriculture data	Ministry of Agriculture	Need to collect
Transportation data	Ministry of Tourism	Need to collect
GIS maps	Public websites	Largely collected
Environmental data	Environmental Inspection	Need to collect
Energy consumption/demand/ availability	MEWD Ministry of Commerce Ministry of Education Ministry of Health Ministry of Agriculture Ministry of Tourism	Partially collected

There are several challenges in data collection. The first challenge is that the RRA experts have to clearly identify the data format needed for this specific assessment. Another one is frequent unwillingness of various agencies to disclose the data. The important role of the leading experts in this case is to explain the goal of the data collection to these organizations, request only relevant information, and to be very persistent and consistent in contacting the organizations and obtaining the requested information.

During preparation of this report, the expert team was able to collect a significant amount of country data, including:

- GIS maps of Zambia, including cities, villages, provinces, rivers, lakes, wetlands, roads, railroads etc.;
- River stream flow data;
- Rainfall data;
- Wind speed data;
- Energy availability and demand in schools;
- List of industrial enterprises;

- Various maps, including electrical grid maps and geographical maps.

A detailed list of the collected data is illustrated in the Appendix 1.

The team also identified additional data that would need to be collected to complete the Rapid Resource Assessment before preparing the Rural Electrification Master Plan. This data includes, but is not limited to the following:

- Detailed solar irradiation data, including GIS maps;
- Geothermal resource data, including GIS maps;
- Measured wind speed data in the locations of actual potential sites for wind generators installation, different from the location of the meteorological stations;
- Agricultural production/farming information, and estimated energy demand;
- Actual diesel generation installations and their status;
- Plans of ZESCO electric grid extension development;
- GIS maps of existing power grid;
- Energy demand of the industrial plants, and GIS maps;
- Energy demand of hospitals, and GIS maps.

Below is the description of the data gathering process during the preparation of this report, with analysis of that collected data. The data and information can be combined into three large categories: energy supply resource, energy demand, and existing and planned electrification projects in the country.

1.4.1.1. Hydro Resources Data and Assessment

The Hydro Unit of the Ministry of Energy and Water Development is keeping an inventory of the stream flow measurements throughout the country. This department has a GIS group that uses ArcView GIS software and digitizer to digitize the maps and convert the data into the GIS formats. It is planned to make this information available for the other institutions that may need it in their work. The World Wildlife Fund (WWF) has installed a network in Lusaka that is supposed to join the local networks of the Hydro Unit, ZESCO, DWA (MOE), WWF, Zambia meteorological Department and Zambezi River Authority. A detailed map of Zambia and its rivers and lakes was provided by the Hydro Unit. Currently, there are approximately 130 functioning river flow metering stations throughout the country, and the Hydro Unit contracts local residents to perform daily flow measurements at those locations (see Picture 1). Historically such data is available in a table format for previous 30-40 years, however often the data is missing for various reasons. The GIS locations of the 130 metering stations were made available by the Hydro Unit of the MOE, and for 70 metering stations stream flow measurement data in the table format were provided for the period of 30-40 years as well.

Additional data for hydro resource assessment was obtained from the Department of Meteorology. The Department has a database with the data on precipitation and wind for the past 50 years. The precipitation (rainfall) data can be useful (i) in the near term to fill the gap in case if the river stream flow data would be unavailable in certain regions, and (ii) later during the phase of a detailed energy master plan preparation for detailed assessment of regional energy potential. The rainfall data was obtained in the form of sampling files with average rainfall data throughout the country, per each meteorological station location (39 total), for the representative period of past 30 years. This data was converted into GIS format.

Another important source of information for the hydro resource assessment, provided by the Hydro Unit, was a Water Development Master Plan prepared by JICA in 1995. This is a detailed study that contains comprehensive analysis of Zambian water resources and offers the options and potential projects for development of these resources for various purposes including the household water supply with potable and technical water, irrigation, other agricultural needs, and large electric hydro projects. This study, however, did not include the analysis of possible small, mini and micro hydro projects.

More information about the hydro resources and potential projects was derived from the report “Small Hydropower Preinvestment Study for North-Western province prepared by the Norwegian company NORAD under UNOPS program in 2000. This study analyzed ten potential hydropower projects of various scale, from 0.1 MW to 1.2 MW. It is similar to other studies done in the country, and illustrates that the main focus given to small and mini hydro projects, with the size of the generating plant larger than 100 kW, while micro hydro projects capable of supplying electricity to a single home or a small village were not investigated. However, one of the economical solutions for rural electrification in Zambia, where the villages can be as small as a dozen of single family houses and settlement patterns are dispersed, would be application of the off grid micro hydro projects under 0.1 MW. This study did not address projects of such a small size.

Analysis of the Stream Flow Data

Stream flow data was obtained from the Hydro Unit of the Ministry of Energy and Water Development, for the 69 locations of the operating metering stations, as illustrated in Appendix 2, for the following river catchments:

- Chambeshi Catchment
- Kafue Catchment
- Tanganyika Catchment
- Luangwa Catchment
- Luapula Catchment
- Zambezi Catchment

Appendix 3 illustrates the initial format of stream flow data, including the metering station location and commissioning date, the catchment’s area and the measured daily average flow rate during a year when the measurements were performed. This data is gathered on a daily basis by local contractors. This data is a reliable source of information, however, for some years and months it is missing. The data on each of the 69 locations was summarized by the average annual maximum, minimum, and mean flow, as it is shown in Appendix 4. In order to install micro hydro plants to provide sustainable energy supply, the rivers in those locations must have consistent flow throughout the year. Therefore, the summarized table and the initial data sets were analyzed for the presence of the months with zero flow in the rivers. The analysis revealed that for most of the years for the majority of the locations, there are days or even months without the flow data. However, in many cases, this can be attributed only to the missing data. Such locations were included in the further analysis, while those with zero flow during the dry season, were considered unfeasible and excluded from the further analysis. The table representing the final list of the sites, for which the stream flow data is consistent and sufficient for analyzing the technical feasibility of hydro plants installation is illustrated in the Appendix 5. The data in this table was ranked by the mean flow during the year.

Most of the sites near the location of the river flow meters can be considered for micro or mini hydro plant installation, while several locations are suitable for mid size hydro plants. As an example, the location at Kaleen Hill was analyzed (Zambezi River, metering station No.1080). It is located in the North-Western Province, Mwinilungu Region, near Kalene Hill Mission, as illustrated on the exhibit Figure 3 below. There are 4 villages around this area, and six schools that do not have electricity. Installation of an off–grid hydro power plant would provide electricity to these places.

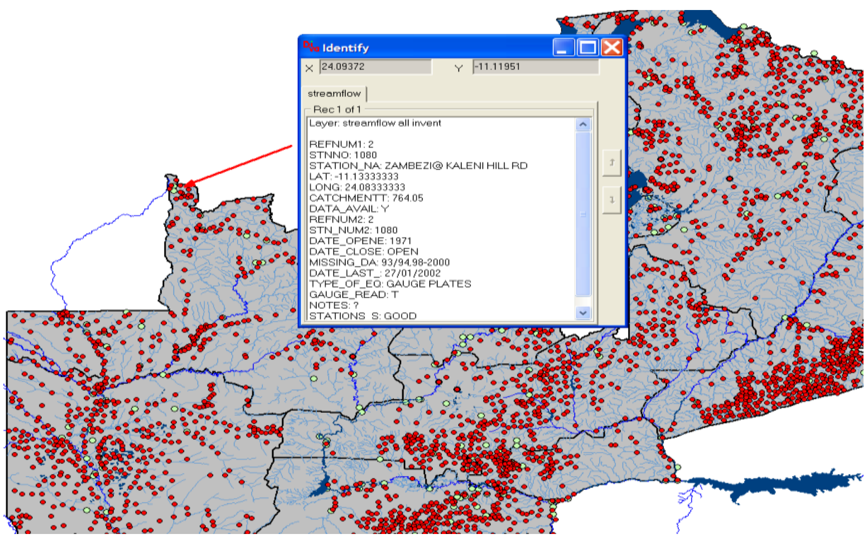

Figure 3: GIS map illustrating river flow measuring stations and location of schools without electricity supply.

Homer estimated the potential for mini/micro hydro at this location. The flow data was averaged, and the average minimum flow was used as a baseline for calculating the parameters of a hydro plant.

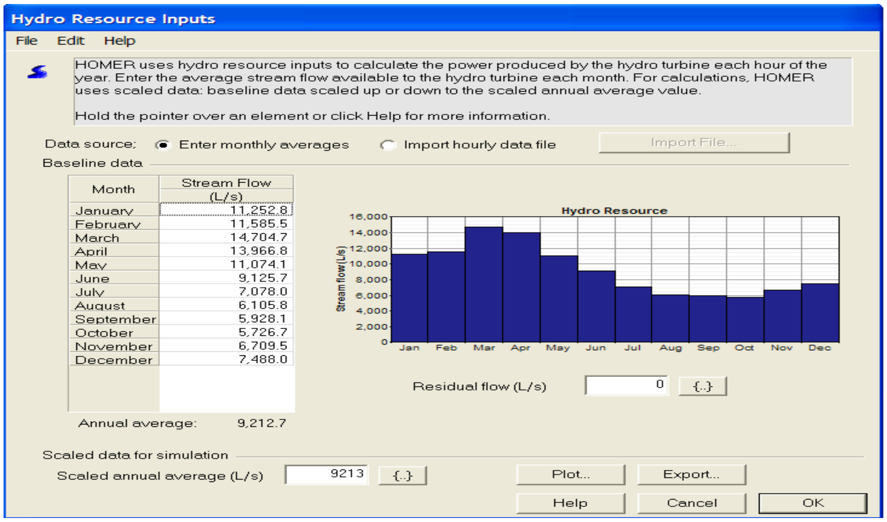

Figure 4: Example of the initial river stream flow data input in HOMER.

The available water flow allows one to design micro or mini hydro power plants of various sizes. The sizing of a micro hydro plant is always very site specific, and depends on two main factors: water head and water flow. The length and diameter of a pipe delivering water from intake to turbine is also considered as a limitation factor. In order to investigate in detail the potential projects near the river flow metering stations, additional information needs to be gathered or produced such as: water head, distance from the river to generation point, distance from the generation point to consumer, and actual demand at the user. Therefore, for sample HOMER analysis, hypothetical numbers for water head and distances were assumed. The exhibit below illustrates the process of modeling a micro hydro plant based on the above flow data.

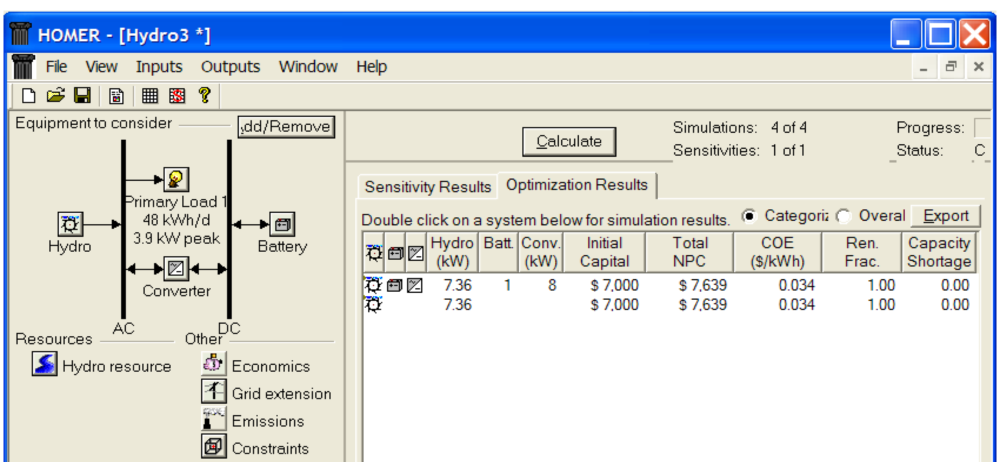

Figure 5 Example of HOMER model for micro hydro plant

At the present time, the information on the stream flow represents the best basis for prioritizing the available hydro resources. The next step of the Rapid Resource Assessment should build upon the above list of prioritized locations, and collect additional data to facilitate modeling of potential micro hydro power plants. Additionally, for the locations where the stream flow data is not available or cannot be obtained with reasonable efforts, rainfall data should be used as estimates. The rainfall data was collected from the Meteorological Department for 39 sites, where the meteorological stations are installed. The data is illustrated in the Appendix 6.

1.4.1.2. WIND RESOURCES DATA AND ASSESSMENT

The Meteorological Department of Zambia is in charge of collecting the measurements on wind speed across the country. There is a total of 39 meteorological stations in Zambia, as illustrated on the below map generated by Dive-GIS:

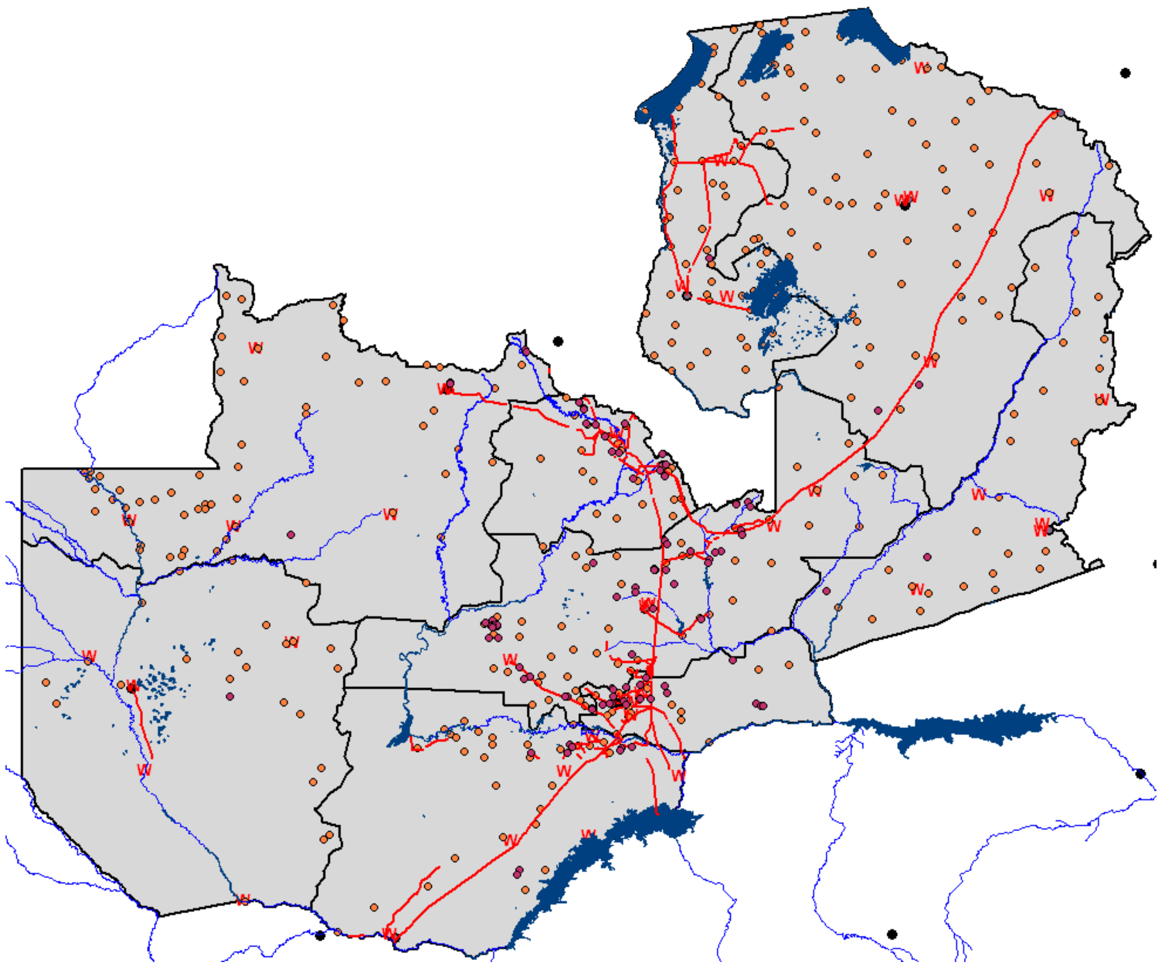

Figure 6 GIS Map of Zambia with the locations of the Meteorological Stations and High-Voltage Transmission Lines (330-220 kV)

The Department possesses a database of direct wind speed and rainfall level measurements for the past 50 years. For the purpose of the RRA, the file was generated from the database for all 39 stations for the representative period of up to 30 years depending on the availability of the measurements at certain locations. The geographic coordinates of the station locations were provided along with the measurement data, which allowed conversion of this information into GIS format. The data includes geographic coordinates of the meteorological stations, wind speed in meters per second, and number of years this measurement was averaged for. The collected complete set of the measurements is illustrated in the Appendix 7.

According to international experience, the minimum wind speed that can make electricity generation economically feasible is 5 m/s. According to this number, and to the available measurements, there are only seven locations that can be used for wind generator installation, as illustrated below:

Table 3. Locations with Wind Speed Greater than 5m/s

Station	Longitude	Latitude	Wind (m/s)	No. of Years
KABWE MET	28.48	-14.42	5.9	27
MONGU	23.17	-15.25	5.9	17
MKUSHI	29.80	-13.60	5.5	3
CHIPEPO	27.88	-16.80	5.2	2
LUSAKA HQ	28.32	-15.42	5	16
LUSITU	28.82	-16.18	5	6
KALABO	22.70	-14.95	4.9	11

From the GIS Map below, which illustrates the locations of these sites, it is clear that the higher wind speeds are occurring along the 330/220 kV transmission backbone in the Western, Lusaka, and Central provinces. While the towns of Mongu and Kalabo in the Western province are supplied from the 66 kV power line coming from Victoria Falls HPP, and there is a potential for the development of the distribution electric grid to the surrounding districts, these surrounding districts can benefit from using the wind power for electricity generation. As an example, a comparison of a wind turbine and diesel generator installation was performed, using the Homer model. Depending on the load, the price of diesel fuel, and other factors, such as the type of equipment and its cost, and project life cycle, the most economical electrification option can be using a wind turbine in conjunction with a diesel generator. However, the overall solution for a small stand alone home with daily load of 0.2 kW, using both generator and wind turbine is not very attractive economically, as the cost of energy is over $0.8/kWh.

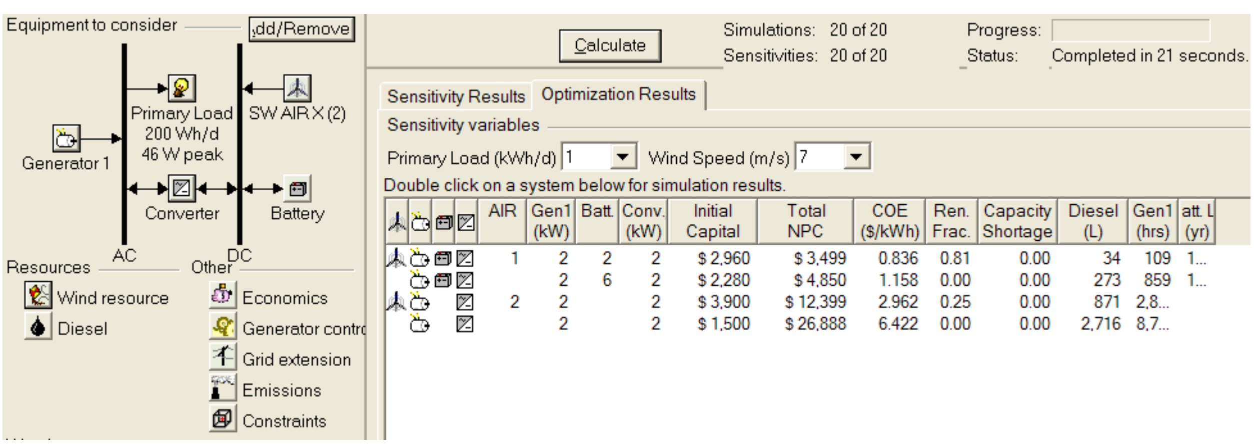

Figure 6. Comparative analysis of wind turbine and diesel generators off-grid systems

Census Data

2000 Census data was obtained from the Central Statistic Office (CSO) of Zambia. This report was compiled during four years and became available in 2004. The project experts obtained a hard copy of the Census Report, as well as an electronic copy of the database that was a basis for this report. The database (ZamSED) contains information on a very broad spectrum of social and economic indicators. It allows the user to select the required data by a sector of the economy or social indicators. For the purpose of RRA, various sets of data, down to Ward level, can be generated from ZamSED for analysis of the potential energy demand, including the following examples:

- Number of household with access to electricity and water;
- Proximity of the schools to the towns/villages;
- Agricultural production in various regions;
- Number of economically active population;
- Gross domestic production;
- Number of households using electric home appliances, etc.

These types of information allow experts to analyze the economic and social activities throughout the countries, and identify the regions that could economically benefit from implementation of the electrification projects, both off-grid and grid connected.

School Data

The Zambian Ministry of Education, with the assistance from USAID, The World Bank and other donors, developed a database on all existing schools in the country. This database (EDASSIST) is a source of comprehensive information, including demographic data, school locations, number of pupils, financial and infrastructure data etc. The figure below illustrates a sample screen for data selection:

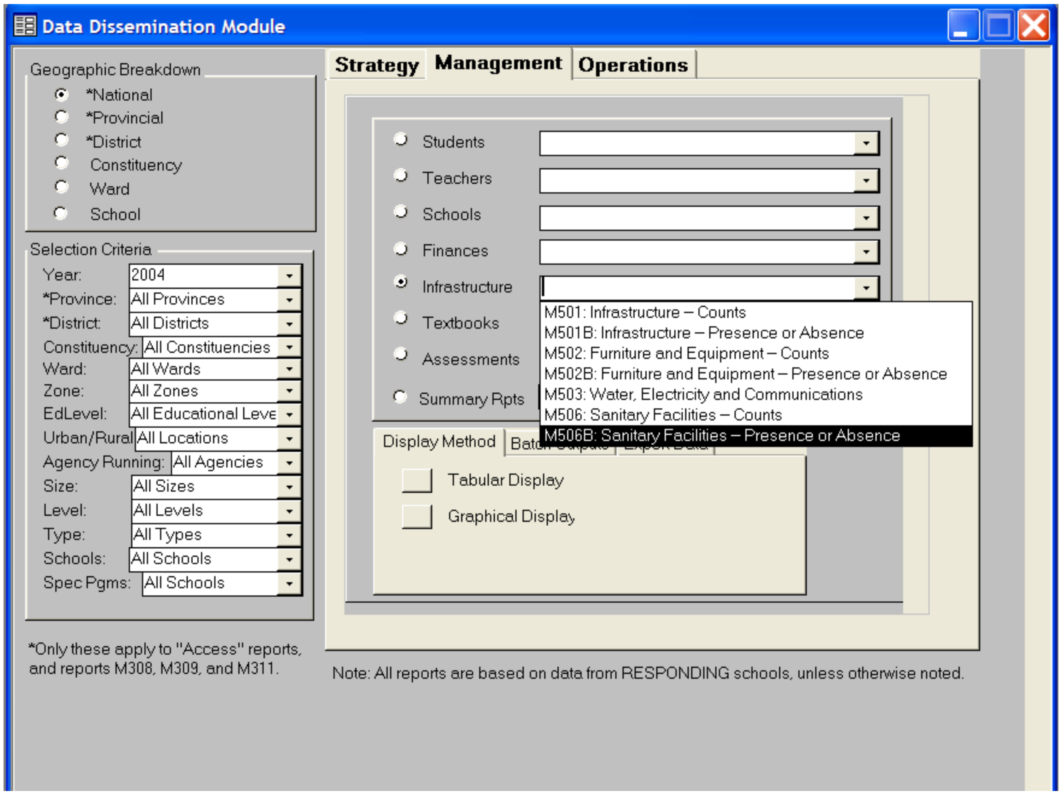

Figure 7. Data selection menu of the EDASSIST database

For the purpose of the RRA, the database provides the important information about the availability of energy and water at certain schools. It also allows estimating the energy requirements of the other schools that have electrical equipment, such as computers, faxes and other office equipment.

Industry Information

The information about existing industries, and their locations was made available by the Ministry of Commerce, which conducted an all-country Manufacturing Sector survey in 2003-2004. The survey was done in order to provide statistical information for economic planning and monitoring of performance as well as constraints and potential for industrial growth. Based on the results of the survey, the Ministry designed a database, which is being finalized as this report is being prepared. The database contains such information as, the industry location, its ISIC code, ownership, types and list of products, various financial indicators of the enterprises, raw materials, applied technology and equipment, export/import data, and various constraints, including electricity, water, fuel and other. Although the information in the database does not provide direct answers on the actual industrial energy demand (consumption), it indicates the level of sufficient availability of fuel and energy to a particular business. Also, it allows the experts to estimate the level of current industrial production in the region and the potential production areas thus providing for educated estimate of the energy demand that can be used for modeling purpose. The information about

Zambian Manufacturing Sector, obtained during the project mission, is illustrated in the Appendix 8.

Status of various Rural Electrification projects proposed or currently under implementation in Zambia

The Ministry of Energy and Water Development (MEWD) is the Government's principal entity charged with national energy planning and policy development. The Government has stated that increasing access of electricity to rural areas and the provision of all forms of energy to promote rural economic development are two of its key priorities. In order to concentrate the efforts of the Government and various donor organizations working in Zambia on rural electrification in one agency, a Rural Electrification Authority was established in 2004. Its main goal is to identify and prioritize the rural electrification projects, and implement them using the Rural Electrification Fund (REF). The REF is filled mainly from the levy that is a part of the electricity tariff.

The Ministry of Energy and Water Development and the Rural Electrification Authority (REA) developed a list of immediate rural electrification projects, of the total estimated cost of the projects was approximately 12 billion kwacha (approximately US$2.8 million). However, only 700 million kwacha (US$160 thousand) was available to the Rural Electrification Fund (REF) managed by the (REA), to finance on-going projects in two provinces. At the present time, the REA and the MEWD possess a long list of applications for local electrification projects from various provinces and districts of Zambia. However, financing of such projects is hampered by the lack of funds in the REF.

The majority of the rural electrification projects are still funded by the donor community. In 2000, seven projects were funded to extend electricity to seven provinces in Zambia: Chisamba Farm Block; Central Province; Gwembe-Tonga, Southern Province; Chembe, Luapula Province; Lukulu Farm Block, Northern Province; Tapo-Lukona, Western Province; Manyinga Sub-Boma, Northern Province; and areas in Katete, Eastern Province. These projects were funded by the Zambian Government under financing from several bilateral donors.

However, ZESCO and private investors have also provided significant funds for the development of its distribution grid extension to the rural areas. There are 64 projects on the ZESCO list approved for financing. Total funds, provided by 2005, for implementation of these projects amounted to approximately 2.5 billion kwacha (US$3 million). One of the focus areas of ZESCO electrification programs was the farmer community in Zambia. In order to increase the production of maize and other crops through irrigation, ZESCO, in cooperation with the Department of Energy of MEWD developed a mechanism that enables farmers to irrigate via a reduced cost for electricity. Under this mechanism, the electricity demand charge had been reduced by 50% for irrigation purposes. ZESCO signed an agreement with the Zambia National Farmers' Union to deploy this mechanism.

The Swedish Government is helping Zambia implement a project to offer solar electricity services to 400 homes through Energy Services Companies (ESCOs) in the Chipata, Lundazi and Nyimba Districts of the Eastern Province. The Ministry of Energy and Water Development (MEWD) and the Swedish International Development Agency (SIDA) have implemented a sizeable pilot solar PV project in the Nyimba, Chipata and Lundazi districts in the Eastern Province. A number of energy service delivery companies are being utilized to implement the projects. The project, since 1998, has provided electricity services to rural areas for lighting, water pumping, and refrigeration. The sectors where application has occurred included medical facilities, households, NGOs, schools, small businesses, and tourism. A total of 350 solar PV installations have been completed. The largest number (230) of applications has been in refrigeration systems.

Norplan A.S. has completed a Small Hydropower Pre-Investment Study for North–Western Province. The districts of Mwinilunga, Kasempa, Kabompo, Zambezi, Lukulu and Watopa were considered for potential implementation of electrification projects, including electrification of schools, hospitals and a few small-scale industries. The evaluation of projects involved considering many factors, such as technical issues, environmental and social-economic issues, current and future demand, and economical issues. The study analyzed 10 small hydro power plant projects in North-Western province, and six projects were selected for detailed feasibility study. These projects, that represent an alternative to existing diesel generation, were ranked according to their technical potential to supply the surrounding host of towns. Table 4 illustrates the project rankings.

Table 4. Small Hydro Project in North-Western Province

Load Center	Project Site	Capacity
Mwinilunga	West Lunga river	1.2 MW
Mwinilunga	Luakela river	1.2 MW
Zambezi	Chavuma Falls	1.2 MW
Kabompo Boma	Chikata Falls	1.2 MW
Kasempa	Lufupa river	0.23 MW
Kabomopo Boma/Manyinga	Manyinga bridge	0.1 MW

Out of six potential sites potentially feasible for the development of power stations, the study identified two projects as being economically viable for implementation. These project sites were Shikata Falls and West Lunga river. The estimated capacity of these projects was 3.5 and 2 MW respectively. Based on the combined technical and economical analysis, the study recommended development of 3.5 MW hydropower plant at Chikata Falls for supply of Kabompo, Manyinga, Mumbeji and Zambezi; and development of 2 MW hydropower plant in West Lunga for supply of Mwinilunga. It was recommended to construct 33 kV transmission line between Mutanda to Kasempa to replace the existing diesel generation that will continue operation until alternative supply sources are developed.

Another on-going rural energy project is being implemented in the Kaputa and Chinsali districts of the Northern province, under financing from the Global Environmental Facility

(GEF). This project provides for installation of isolated mini-grid systems, based on renewable sources of energy to produce electricity.

The project includes three following components:

- Installation of a 1,000 kW mini-hydro plant at Shiwa Ngandu estate in Chinsali district replacing existing diesel generators. The mini-hydro will provide power for the irrigation of coffee and sugarcane plantations; processing of coffee; and expanding the hammer mills to grind grains. Also, it will supply power to the local hospital and health center, which currently use a combination of diesel engine and PV to pump and treat water from the local lake. Additionally, power will be supplied to 100 residential houses and to the grid. The cost of this mini–grid is US$1.54 million.
- Implementation of a 1,000 kW biomass gasification project in the Kaputa district, which has abundant biomass resources. The US$2 million project will replace 500 kW diesel generator plant owned by ZESCO and provide electricity to customers through the existing local grid.
- Implementation of a 45 kW PV pilot project at Chinsanka in the Samfya district, including installation of solar lanterns for fishing at night. Chinsanka is the largest commercial center in this district. The PV mini grid will serve 450 houses and 50 shops. It is projected to have 25% overcapacity to meet future demand increase. The estimated investment cost for this project is US$1 million.

2. Using RRA in Zambia

2.1. Applying the RRA Methodology

At this stage, the RRA methodology has no definitive metrics in regards to the choice of regions for likely new electrification projects. In the past, when grid extension was the ruling paradigm, proximity to the grid was paramount and the grid crept along into new areas incrementally, except in areas where electrification was seen as a political tool. Using the RRA, the main idea is to find areas that can support a small system and that either currently have, or can easily develop, a demand profile that makes such a system reasonably self-supporting.[3]

So the first criterion for possible success is that an area may be able to use a system that is more than rudimentary. By more than rudimentary, we mean:

- Electricity is used for light industry, agro or forest processing;
- There is extensive daytime demand for electricity;
- Electricity can add value to local agricultural, fishing or forest product output;
- There are institutions such as schools and health centers that can use electricity during the day; and
- There is a reasonable expectation that demand will grow beyond the capabilities of the proposed system within five years.

Once an area has been selected that might potentially support a new electricity supply system, more detailed investigations are needed into the precise nature of that demand. These investigations will include the following types of information:

- Potential load curve;
- Potential for electrification of current processing or finishing activities;
- Potential for expansion of raw material output through better storage or water pumping;
- Extent of resource base for new economic activity or expansion of existing activities.

In order to assess whether and, to what extent, this proposed methodology can identify areas that are appropriate for new rural electrification, the team chose two different regions of the country and evaluated supply and demand conditions in those areas. ***The team wanted to assess the potential for regions that are not obvious candidates for new electricity supply initiatives from ZESCO or from Copperbelt***

[3] Reasonably self-supporting is, like many terms in the RRA lexicon, somewhat imprecise. It is not expected that any very poor region in rural Zambia can support the full cost of new electricity service, whether it is grid extension or a village system. However, an area that possesses the appropriate characteristics for a desirable demand profile will stand a better chance of supporting such a system than is an area where the economy simply cannot provide adequate use for or infrastructure for more than a rudimentary system.

Energy. As an initial *negative screen*, the team chose two regions that satisfied the following conditions:

1. No relation to improved conditions in the copper industry;
2. No relation to development of the new commercial farming areas;
3. No relation to new trading and economic ties with Tanzania

Two regions of the country appear to be potential candidates for new projects based on information from the RRA and the analytical models. These are the Western region and the Eastern region. The information on these areas, which provides the rational for selection for an investigative effort, is given in the next section.

2.2. Examples of Using the RRA Methodology

In order to show what can be done using the GIS and Homer approaches to project identification, the team chose to select a pair of (general) locations for analysis, one from the Western province and one from the Eastern province.

2.2.1. The Western Province: Water Pumping & Forest Products

2.2.1.1. Western Province Demand

The Western Province of Zambia is one of the poorest regions of the country. Landlocked, far from markets, and without mineral resources, this province remains largely without industry and with minimal electricity supply, despite the waters of the Zambezi River, which flow through much of the province in a southerly direction.

Tables 5 and 6 below, show the current population statistics and major industries of the province.

Table 5 Household Characteristics in Western Province

Province	Area Name	Households with access to electricity Percent	Households with radio Percent	Households with telephone Percent	Households with television Percent	Number of agricultural households	Population in agricultural households	Total households
Western	Kalabo	1.57	20.08	0.20	1.55	22,527	103,222	23,970
Western	Kaoma	2.71	28.29	0.40	1.80	25,182	129,897	29,984
Western	Lukulu	0.87	19.86	0.35	0.52	12,383	57,272	13,488
Western	Mongu	8.06	31.75	1.94	9.74	23,326	112,736	32,054
Western	Senaga	2.71	21.03	0.44	1.66	18,483	92,899	20,956
Western	Sesheke	3.31	36.28	0.41	4.68	14,218	64,938	15,929
Total(average)		3.21	26.22	0.63	3.33	116,119	560,964	136,381
National averages		16.7	42.7	3.2	17.6	1,232,301	5,853,209	1,884,741

Source: ZAMBIA_CENSUS00, Zambia 2000 Census of Population and Housing, CSO, 2003

The Western Province is not the smallest in the country. Nor are its statistics on education, electricity penetration, living standards and so forth, the most dire in the country. Nevertheless, the Province lacks significant economic infrastructure to take advantage of its two main natural assets – wood and water.

The next table shows the level of industrialization in the province. There are four food-related industries and two industries oriented toward the forestry resources. A look at the GIS, though, indicates that there is significant additional forest product potential in the province. However, without a means of processing the timber, it is unlikely that this potential can be realized.

Table 6: Industrial Establishments in Western Province		
Company Name	**Type of Industry**	**Location**
Western Cashew Industries Ltd	Food	Limulunga Royal Village
M.J Bakery & Commodities	Food	Mongu
Mongu Joinery	Sawmills	Mongu
APG Milling Limited	Grain mill products	Mongu
Country Bakers	Food	Mongu
Sasha Timber Ltd.	Sawmills	Mongu

The province was chosen because of its potential for development and because further development can be based on existing industries.

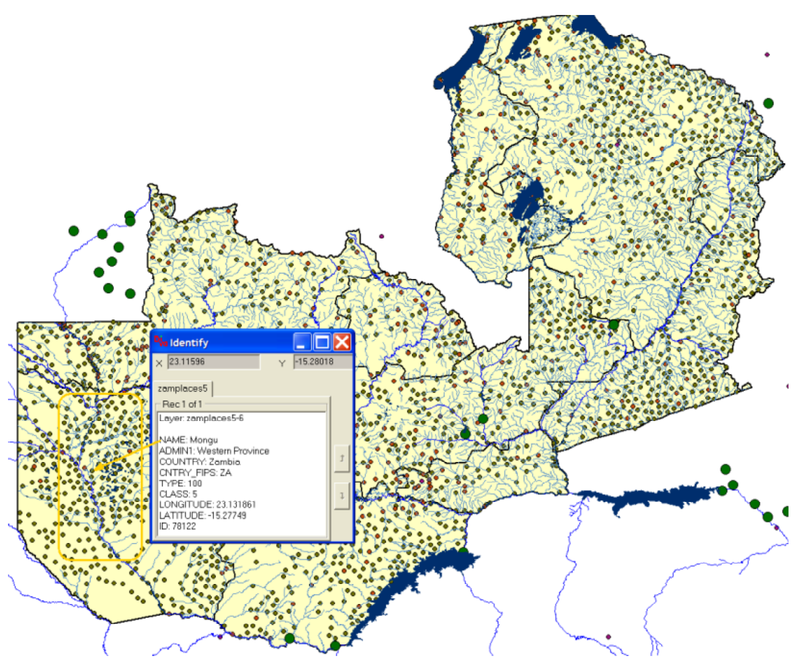

Figure 8: Area in Western Province With Potential For Forest Products and Irrigation

The area surrounded by the yellow line in Figure 8 delineates the region in Western Province that appears to possess significant potential for irrigated agriculture. The village centers and main towns and villages are displayed on the map. According to the information of the Water Affairs Department of the MOWED, the area west of Zambezi River has a very good potential for irrigation agriculture development for two main reasons:

1. There is significant vegetation along the banks of the river, creating enough biomass to provide a functional natural fertilizer.
2. The underground water horizons can often be found as little as 2-5 meters below the surface in this area, so that pumping water from the aquifers can be a feasible task assuming sufficient power supply is provided to run the pumps.

The constraints for agricultural development in this area, and further to the west, are a relatively low density of populations (the villages are of small size and often are scattered across vast areas of land), proximity of the desert, as well as an unstable border situation with Angola. However, appropriate land and financial policies accompanying a small RE project in this region could provide incentives for new residents, especially, if there were greater local processing ability.

The map below shows the forest cover of the country, indicating the potential for additional value added in forest product processing in the Western Province.

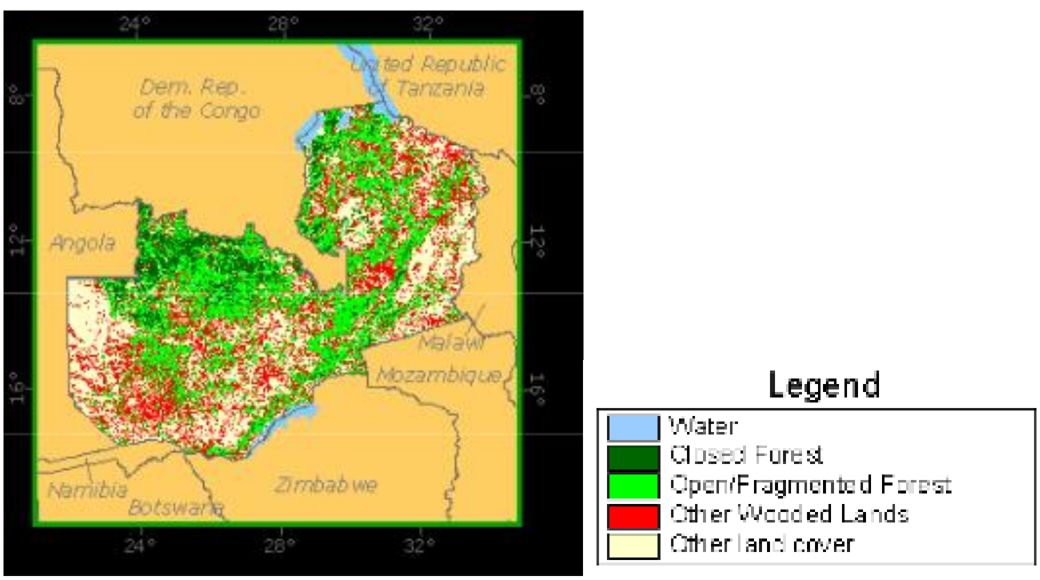

Figure 9: Forestry Map of Zambia

Source: *thewoodexplorer.com*, Country Data for Zambia

The Zambezi River basin in the Western Province can be seen as the light green area. The forested area in question is to the west of the River itself. At the present time there is an existing small scale forest products industry in the region, with two sawmills. There is also some agro-processing, with grain mills and bakeries in the local economy.

2.2.1.2. Electricity Supply

Electricity to this area is supplied via 66kV power line that goes from the Victoria Falls hydro power plant through the town centers of Senaga, Mongu and Kalabo. ZESCO plans to build a 66kV line extension in the direction of Luculu, Zambezi, Chavuma, Kaoma, and Kabompo towns. However, the rural villages do not have electricity supply and would benefit from the small electrification projects. Moreover, this MV extension line is subject to ZESCO's funding constraints as well as its construction timetable. Electricity supply for smaller-scale sawmills and grain mills will be subject to considerable delay, given the slow pace of expansion of power supply outside of the cities and large towns.

2.2.1.3. Candidates for the RRA

Demand for Electricity

A small town of 250 households (~1,500 occupants), outside one of the candidate towns listed above, with a local forest could probably support several small sawmills and perhaps other wood-based industries. The demand parameters for such a village might look like the ones in the following table:

Table 7: Demand Parameters for Each Establishment in a Western Province Small Town

Parameters	kWh/mo	peak (kW)
Household demand	25.2	0.175
Commercial demand	72.0	0.5
Sawmill demand	3849.1	16.2
School	118.8	0.5
Clinic	237.6	1.0

The sawmill in question is an electric powered chain mill, commercially available, with a 2-3 kW draw. Such small electric mills are widely used throughout the world by wood craftsmen to provide the raw cuts for trees that they down themselves for construction or other purposes. It is assumed that each sawmill would have two of these. In addition, each sawmill would have one electric molder capable of producing finished beams and logs suitable for construction.

Now assume that the town is fully electrified, as shown in the Table below:

Table 8: Demand For Electricity in a Developed Western Province Town					
	Monthly Demand/unit			Total Monthly Demand	
	kWh	kW	# Units	kWh	Kw
Households	25	0.175	250	6,300	44
Commercial	72	0.500	20	1,440	10
Sawmills	3,849	16.200	10	38,491	162
School	119	0.500	2	238	1
Clinic	238	1.000	1	238	1
Total for Town/Village				**46,706**	**218**

Such a town, with ten small sawmills, could provide employment in the mills for as many as sixty men, plus the employment in wood supply, including trucks and silviculture. Therefore, this prospect is not out of the realm of possibility for such a town. Total cost (delivered, with tariff) for the equipment for the ten mills would fall into the $100,000 range, again not excessive, given the upside potential for new output and value added within the village (see below for discussion of potential economics of wood products).

Supply of Electricity

Given a peak demand of almost 220 kW, and the need to have reliable supply of power for at least 10 hours daily, it will be necessary to either connect such a town to the grid or to build a local power supply that meets the industrial demand of the town, while supplying houses, businesses and civic institutions.

Two alternative supply modes are possible for this town. The first, grid extension from one of the regional cities, via 11 kV line, would cost $10,000-15,000 per km. For a 25 km traverse, this line would require ZESCO to recover at least $250,000-400,000 from electricity users in this town. A second alternative is to build a system to supply the town's current and projected (5 years) needs.

2.2.1.4. Electricity Supply Economics

Using the Homer model from NREL, the estimated demand for the above town was fed into the model and the cost of meeting the electricity load was calculated for two different combinations of diesel, wind, hydro and storage, as chosen by the optimization routine. Other potential combinations of wind, hydro and diesel might fit the demand pattern, but were calculated to be too expensive by the optimization program.

If ZESCO were able to build an extension and to supply that extension quickly, then grid extension probably provides the least cost solution for such a town. Table 9, below, shows the probable costs for grid extension:

Table 9: Grid Extension Costs ($US)		
Item	**Total Cost**	**Cost/kWh**
25 km line	400,000	0.107
Electricity supply	-	0.075
Total		**0.182**

This means that the full cost of electricity supply to meet the needs of a newly industrializing town would cost consumers on average about US$0.18 per kWh, or about 3 times the existing urban tariff.

The results of the Homer model show significantly higher supply costs. Table 6 gives the results for the Homer solutions:

Table 10: Town Electricity Supply Costs ($US)		
System Configuration (kW)	**Cost/kWh**	**Initial Investment**
1 wind (15/50) + diesel (225) + battery	0.277	779,000
2 wind (15/50) + hydro (43) + diesel (225) + battery	0.294	854,000
Notes: Assumed fuel price of $0.80/liter for diesel, discount rate of 11.5%. In system 1 wind supplies 54% of the electricity, in system 2 wind supplies about 50% and hydro 4%.		

Unless the hydro source is very good, the least cost solution excludes it as a component. No all-diesel systems were found among the least cost solutions.

A full cost-recovery supply of electricity for industrial, commercial and residential consumption of electricity will probably cost at least $0.18-20 per kWh or more with a village supply system operating on a stand-alone basis.

Construction of village systems may make sense, provided funds are available, as a method of (i) providing electricity supply to areas too remote to expect a grid extension in the next few years; (ii) as a way of capitalizing on donor programs to provide self-contained systems where there are beneficial uses for the electricity; and (iii) where grid extension will come within 10-15 years but where the economic benefits of a self-contained system outweigh the costs of waiting for less expensive grid supply.

It should also be noted that the diesel component of a system can be moved to a new location once the grid is connected to a town or village. Given the substantial potential for either wind or hydro throughout the Western Region of the country, it is certainly possible to provide substantial inroads for renewable energy technology using hybrid generation for stand-alone systems.

2.2.1.5. IMPLICATIONS

The analysis results shown above indicate that it will cost roughly $500,000-$1,000,000 to put a village of 1,500 on its feet economically. The joint provision of electricity and the economically beneficial means to use that electricity could generate hundreds of thousands of dollars annually in additional processed wood output. Currently, the country is a net exporter of wood and wood products, but is suffering from rapid deforestation.

With a locally-based wood products industry, there might be incentives at the local level to harvest wood on a more sustainable basis. Moreover, organized sawmills could also start to produce charcoal with the waste cuttings, reducing the use of prime timber for household fuel.

A sawmill can be a good investment, even for a region far from the country's export customers. With a value for a cut 20 m hardwood tree of about 10% of its US value, and assuming the mill can process 20 logs of this type each year, the mill can cover all of its costs, including labor and whole log supply and earn a profit of about $17,000 (on sales of about $50,000). Under such circumstances, it does not appear to be worthwhile to wait for grid supply. Indeed, the sawmills could pay for the household and school electricity (a very small increment), and still find net profits of more than $14,000.

The real hurdle is to find enough money to jointly fund both the electricity system and the investment in the sawmills and the log supply systems. This will probably need to be done using donor funding.

2.2.2. Eastern Province: Water Pumping & Agro-Processing

2.2.2.1. Electricity Demand

The Eastern province of Zambia is proximate to the borders and markets of Mozambique and Malawi. The area is far more densely populated than is the Western Province and contains far more industry as well. The map on the following page shows the region of interest.

Although the region is supplied with electricity through an existing HV line and, indeed, there is local hydro-based generation of electricity, the second map shows that the schools in the region are largely unelectrified. Therefore, obtaining the added value of electricity services for water pumping or local processing of output is not currently possible.

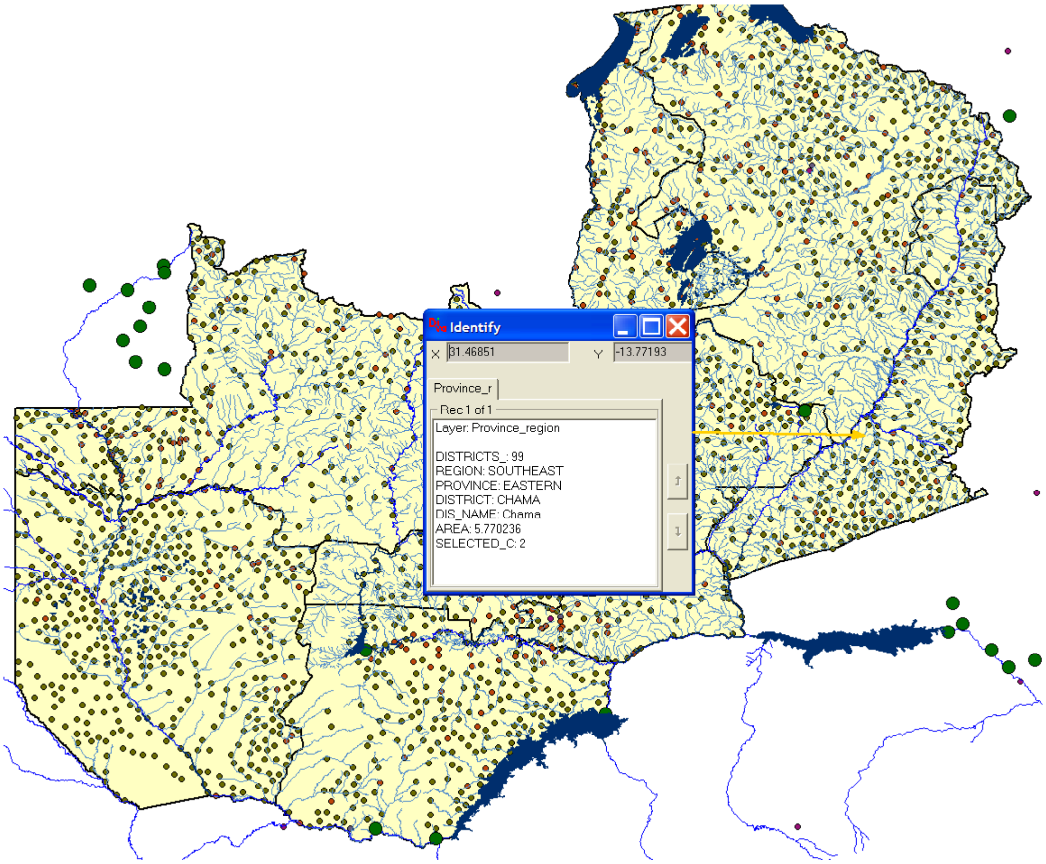

Fig.10. GIS map of the Eastern Province with major towns and villages locations

Table 11: Household Characteristics in Eastern Province

Area ID	Area Name	HHs with access to electricity Per cent	HHs with radio Per cent	HHs with telephone Per cent	HHs with television Per cent	Number agriculturl HHs	Population in agricultural households	Total households Number
Eastern	Chadiza	1.76	37.56	0.28	2.37	15,147	76,655	15,928
Eastern	Chama	0.38	27.62	0.13	0.35	13,800	67,388	14,397
Eastern	Chipata	6.97	44.05	1.16	10.44	58,047	289,970	70,347
Eastern	Katete	1.76	35.36	0.33	0.73	34,777	166,798	38,387
Eastern	Lundazi	0.64	34.31	0.25	0.78	43,745	213,788	46,178
Eastern	Mambwe	3.99	40.27	0.34	2.44	8,844	42,341	9,578
Eastern	Nyimba	0.13	37.23	0.11	0.39	12,169	61,576	13,201
Eastern	Petauke	1.94	36.87	0.31	1.18	44,591	216,529	46,587
Total (average)		**2.20**	**36.66**	**0.37**	**2.33**	**231,120**	**1,135,045**	**254,603**
National averages		**16.7**	**42.7**	**3.2**	**17.6**	**1,232,301**	**5,853,209**	**1,884,741**

Source: ZAMBIA_CENSUS00, Zambia 2000 Census of Population and Housing, CSO, 2003

Although the electrification rates in the province are below those of the Western Province, more households have radios, though fewer have telephones and televisions.

The Eastern Province is also important politically, as it contains roughly 20% of the nation's agricultural population.

According to the Ministry of Commerce industrial Survey (2004), there are sixteen major industrial enterprises in the Eastern province. With two exceptions, these activities are located in the city of Chipata.

Table 12: Key Industries in Eastern Province

Name of the company	Type of Industry	Location
Super Garage & Millers	Metal products	Chadiza
Sikunya Oil Products Ltd.	Cordage rope and twine	Chipata
Chikunto Building Contractors	Construction	Chipata
Rainbow Milling	Grain mill products	Chipata
Supernova Brewing Corporation Ltd.	Brewery	Chipata
Clark cotton (Z) Ltd.	Spinning	Chipata
Chipata Bakers	Food	Chipata
Jambo Bakery	Food	Chipata
Kwacha Milling Company Ltd.	Grain mill products	Chipata
PC Workshop	Computer service	Chipata
Shawa Engineering Ltd.	Metal products	Chipata
Highway Baker & Confectioners	Food	Chipata
Mako Ni Mako Coffin Workshop	Furniture	Chipata
Chikutano Auto services	Auto service	Chipata
Lundazi Village Industries Service	Metal products	Lundazi
Chinkhombe Oil Millers	Food (Oil)	Chipata

As the table shows, this province has a more varied and diverse industrial base than does the Western Province. Yet, in looking at the vast number of schools in the province without electricity, as shown in Figure 11, there appears to be significant scope for a local electricity supply for villages that are more than 50 km from the grid.

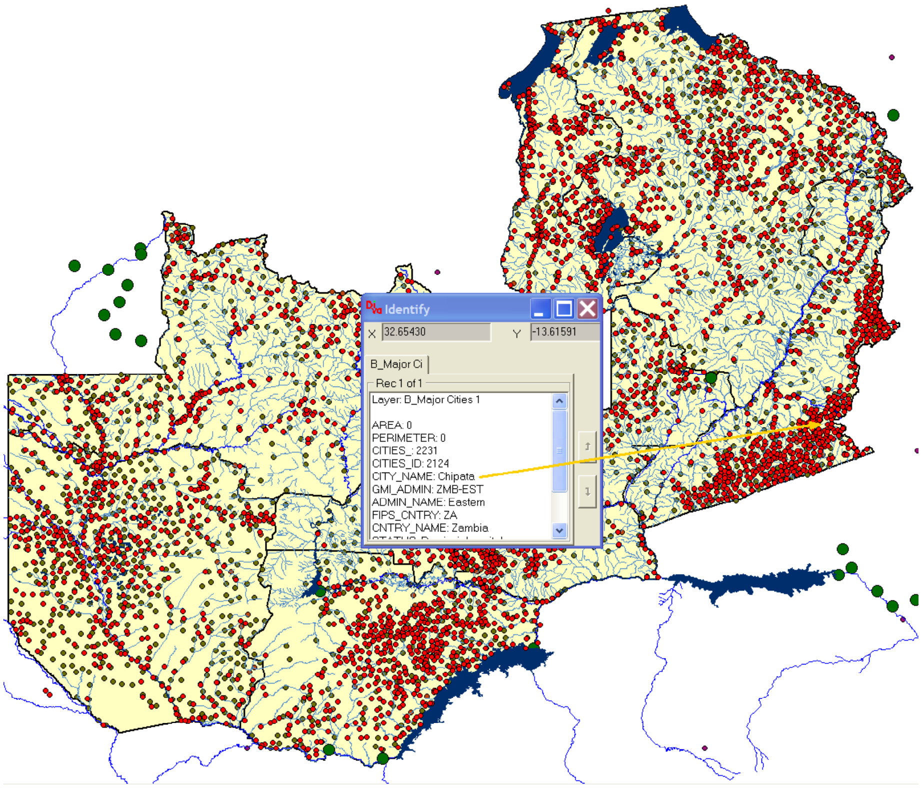

Figure 11: Schools Without Electricity in Eastern Province

2.2.2.2. Electricity Supply

The main source of electric supply in this area is Lusiwasi Hydro Power plant (12MW) from which the power is supplied via 132 kV line to Msoro town, and then transmitted via 66kV power lines that spoke out to Azele, Chipata, and Mfuwe towns. Parts of the province to the west of Azele do not have grid-supplied electricity, nor does the area to the south of the main provincial city of Chipata (arrow in Figure 11 points to Chipata). Zesco anticipates installing a 40 MW extension of the Lusiwasi hydro station. However, some of that output is destined for sale to Malawi via a 132 kV line now under study. In any event the new supply is all to the north of the densely populated farming communities along the Mozambique border region.

2.2.2.3. Adding Value in Local Agriculture

A project to fully irrigate local agriculture, adding two small (100 kg/day) grain mills using local electricity supplies, could add more than $250/year to the average household income in a 250 household town. The tables below show the calculations for electricity supply and pumping and processing energy that would be involved in putting together a complete supply for a small town of about 1,200-1,500 people.

Table 13: Individual household/device Demand Characteristics		
Parameters	**kWh/mo**	**peak (kW)**
Household demand	25.2	0.175
commercial demand	72	0.5
Processing demand	2376	10
Agro pumping demand	224.64	2.4
school	118.8	0.5
clinic	237.6	1

The peak demand for such a town would probably fall into the range of 190-200 kW in a month where both the pumps and the mills were operated. The following table shows the calculated demand for that area.

Table 14: Monthly Demand Characteristics					
Demand For Electricity	**Demand/unit**			**Total Demand**	
	kWh	kW	# Units	kWh	kW
Household	25	0.18	250	6,300	44
commercial	72	0.50	15	1,080	8
Processing	2,376	10.00	2	4,752	20
Agro pump ing	225	2.40	50	11,232	120
school	119	0.50	1	119	1
clinic	238	1.00	1	238	1
Total for Town/Village				**23,720**	**193**

2.2.2.4. Electricity Supply Economics

It appears, from the GIS data base and other information on solar insolation, that the local energy supply situation in an off-grid village will be far more attractive than was the case in the Western Province. In particular, there is adequate scope for both small hydro as well as solar electricity and grain drying.

Investigations using the Homer model indicate that a mixed system, using a diesel baseload supply, with solar, wind or hydro, plus a converter and battery storage, can be economical relative to grid supplied electricity, if the local inhabitants are required to pay the full costs in both cases. To meet a peak demand of more than 200 kW, a system configured as follows will be able to generate electricity for about 20 US cents/kWh. The total investment cost for the electricity generating system will range from about $200,000 for a mostly diesel system, to more than $750,000 for a hybrid system. The net generation costs for the hybrid systems are far lower (US cents 20 v. 27) for the mostly renewable system. However, the initial costs for such a system are 2-3 times greater.

Table 15: System Configuration for Eastern Province	
Prime Mover	Size (kW)
Diesel	225
Wind	30-60
Hydro	8
Solar	0-15
Total	263-300
Note: system uses 48 kW battery to store intermittent energy	

A hybrid system that uses all of the available local resources will cost more than $790,000 initially, but will be able to generate more than 60% of its output with renewable resources, insulating the farmers from future fluctuations in fuel prices.

The economic benefits of this electricity supply would allow an approximately 40% increase in grain output, worth about $450,000 after processing. The costs of making use of such electricity and the additional agricultural inputs required to obtain higher crop yields (seed, fertilizer, herbicides, etc.) would work out roughly as shown in the following table:

Table 16: Agricultural Net Benefits of Improved Irrigation & Processing/Milling				
Item	**Amount**	**Unit**	**# per year**	**Value**
Sales	0.20	kg	2250000	$450,000
Less				
salaries	1,000.00	per person	96	$96,000
electricity	4,981.28	cost of electricity/month	12	$59,775
equipment	35,250.00	total initial cost	1	$11,633
Other inputs	0.08	seed, etc.	2250000	$168,750
Misc	15% contingency			$50,424
Total Additional Costs				$386,582
Net				**$63,418**

As already calculated, this increase in net income is worth more than $250/household, a significant boost in a region where household incomes are less than $500/annually and a disproportionate number of poor and extremely poor inhabitants live.

The system can absorb significant cost increases and still return net benefits to the town's inhabitants. In particular, if the price of electricity were to reach 30 cents/kWh (USD), then the net benefit would fall to less than $35,000, still more than $135 more net income per household.

In a region that is potentially rich in small hydro sites, it is possible to extend the grid to the village or town. However, such a grid extension would probably not result in higher incomes for many years, since most households would not be able to take advantage of the new power supply by investing in pumps of other new technologies without some additional assistance.

As in the case of the Western Province, the new electricity supply is envisioned as a part of an overall package of financial assistance for economic as well as energy development of a small town or cluster of villages. This type of program is essential to making beneficial use of the new supply of electricity.

3. THE WAY FORWARD: Findings and Recommendations

Contained in this report is a methodology for conducting RRA for rural electrification planning. Moreover, this report and our interaction with REA and other Government bodies have demonstrated how RRA can be used to incorporate the goal of rural electrification in Zambia – the development of local economic activity. Two tools have been used in this RRA, HOMER and DIVA. HOMER and DIVA are well suited to the task. They require minimum data, are easy to use and provide robost analyses. REA staff has become familiar with the models through this exercise. Finally, the report lays out the data requirements and how this data is to be collected. The following findings and recommendations are presented

Finding 1: ***Rapid Resource Assessment can be a valuable tool in helping the REA identify, evaluate and rank potential sites and technologies for rural electrification.*** RRA is more cost effective and quicker than traditional rural electrification planning techniques. Moreover, the strengths of this approach reinforce the intent of Zambia's Global Village Energy Partnership – the integration of rural electrification with other development activities and the involvement of local stakeholders. In fact, there was one weakness identified in this exercise and that was the lack of economically available local site information.

Recommendation 1: ***REA can begin using these tools to collect data, analyze sites and ranking them.*** Involving the local communities in the process at the time of data collection and analysis will help to insure their involvement in project implementation. This involvement can only reduce costs, strengthen the probability of success, and ensure more effective integration of rural electrification schemes into local and national economic development.

Finding 2: ***Sufficient data exists for REA to conduct preliminary analyses and rankings.*** Even though our team was unable to obtain all the data which exists, it was able to obtain sufficient data to demonstrate how these tools can be effectively used in moving rural electrification planning beyond the traditional method.

Recommendation 2: REA can work closely with other Government bodies to collect additional data which will enhance the RRA results. This includes:

- Detailed feasibility studies (from the supply side only) that have already been conducted.
- Planning data on schools which will be electrified.
- Information on commerce and industrial activity.
- ZESCO transmission network.
- Resource data such as wind speed, water flow, and solar radiation.

From local communities, the REA can work to collect site specific data such as distance from the resource to the community, income of the households and other household economic activity, and topography.

Finding 3: CORE believes that the REA is now equipped with a tool that it and the consultants it hires under the SIDA funded contract can move forward to quickly screen and rank potential. ***The results of these analyses are invaluable to potential project sponsors. Rural electrification costs and chances of success will be enhanced if REA makes the tools and the results of their analyses available to interested parties.***

Recommendation 3: ***REA can make copies of the RRA screenings and analyses available to interested communities and potential project sponsors.***

Finding 4: ***RRA can be an effective tool beyond mere rural electrification.*** Rural economic development is still a challenge and integrated rural development is one method that is showing promise. Throughout our work the team found that one agency was working on an area that complemented the work of another agency, yet neither know of the overlap. The same applies to data collection and use. For example, the Ministry of Education is collected very detailed data on schools that could be of great use to electricity planners. Commerce was collecting data on industrial activity in rural areas. One donor was funding GIS data on ZESCO's transmission network, yet others were unaware.

Recommendation 4: ***REA can act as a catalyst in GIS information dissemination and in rural development while furthering its own objectives.*** Proper use of RRA and the two accompanying models requires REA to continuously interact with other Government agencies, donors and the local development community. In so doing, it can be the catalyst for developing a community of rural development specialists that share data, analytical methods and tools. REA will develop the DIVA database and this can prove to be an effective source of data and an effective tool for other Government planners.

Our team stands ready to assist REA and their consultants as they move forward to implement RRA.

4. BIBLIOGRAPHY

1. "Angola at a Glance," World Bank, 2001. http://www.worldbank.org/data/countrydata/pdf.
2. "Angola Data Profile," World Bank, 2000. http://devdata.worldbank.org.
3. "Angola Economy," Countrywatch, 2000. http://www.countrywatch.com.
4. "Angola Energy," Countrywatch, 2000. http://www.countrywatch.com.
5. "Angola," Energy Information Administration, 2000. http://www.eia.doe.gov/emeu/cabs/angola.html.
6. "Angola: Electrical Power," MBendi, 2001. http://www.mbendi.co.za/indy/powr/af/an/p0005.htm.
7. "Botswana at a Glance," World Bank, 2001. http://www.worldbank.org/data/countrydata/pdf.
8. "Botswana Data Profile," World Bank, 2000. http://devdata.worldbank.org.
9. "Botswana Economy," Countrywatch, 2000. http://www.countrywatch.com.
10. "Botswana Energy," Countrywatch, 2001. http://www.countrywatch.com.
11. "Botswana," Central Intelligence Agency, 2001. http://www.odci.gov/cia/publications/factbook/geos/bc.html.
12. "Botswana," Energy Information Administration, 1998. http://www.eia.doe.gov/emeu/world/country/cntry_BC.html.
13. "Climate Change Mitigation in Southern Africa: Botswana Country Study," 1999. UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Denmark.
14. "Climate Change Mitigation in Southern Africa: Tanzania Country Study," 1999. UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Denmark.
15. "Climate Change Mitigation in Southern Africa: Zambia Country Study," 1999. UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Denmark.
16. "Congo (Kinshasa)," Energy Information Administration, 1998. http://www.eia.doe.gov/emeu/world/country/cntry_CG.html.
17. "Congo, Dem. Rep. at a Glance," World Bank, 2001. http://www.worldbank.org/data/countrydata/pdf.
18. "Congo, Democratic Republic Data Profile," World Bank, 2000. http://devdata.worldbank.org.
19. "Country Perspective on Rural Electrification." 1998. Presented at Village Power '98: Scaling Up Electricity Access for Sustainable Rural Development (October 6-8, 1998, Washington, DC). Zimbabwe Electricity Supply Authority (ZESA).
20. "Developments," Renewable Energy Information Network of Namibia, Polytechnic of Namibia, Windhoek, 2000. http://www.polytechnic.edu.na/reinnam/Developments.htm.
21. "Distributed Generation from Base load to Backyard", Chapter 20, International Electric Power Encyclopedia, PennWell, 1999.
22. "DR Congo Economy," Countrywatch, 2000. http://www.countrywatch.com.
23. "DR Congo Energy," Countrywatch, 2000. http://www.countrywatch.com.

24. "Electrical Power Transmission in Southern Africa," ESKOM, 2001. http://www.mbendi.com/eskomenterprises/powerpages/saf_transmission.h tm.
25. "Electricity [Namibia]," Investment Promotion Network (IPANET), World Bank, 1991. http://www.ipanet.net/documents/WorldBank/databases/namibia/na1iec01. htm.
26. "Electricity," Chapter 5. In Energy in Africa. Energy Information Administration (EIA), 1999. http://www.eia.doe.gov/emeu/cabs/chapter5.html.
27. "Energy Issues in Africa: The ENDA Energy Programme," Environment Liaison Centre International, Nairobi, Kenya (ELCI), http://www.elci.org/energy/EIssues.htm. No date.
28. "Energy Resources on Gender," UN Commission on Sustainable Development, 2000. http://www.earthsummit2002.org/workshop/energyres.htm.
29. "Energy. Coordinated by Angola," 2000. http://www.sadcreview.com/sectoral%20reports%202001/energy.htm.
30. "Environment and Renewable," Chapter 7. In Energy in Africa. Energy Information Administration (EIA), 1999. http://www.eia.doe.gov/emeu/cabs/chapter7.html.
31. "Eskom Unveils Its New Plan to Restructure," Business Day (Johannesburg) 10/1/2001. http://allafrica.com/stories/200110010307.html.
32. "Factsheet No#2: Energy Resources," Musokotwane Environment Resource Centre for Southern Africa. http://www.sardc.net/imercsa/zambezi/zfsheet/zfsheet02.html. No date.
33. "Future Energy Requirements for Africa's Agriculture: Findings and Recommendations of an FAO Study," Environment Liaison Centre International, Nairobi, Kenya (ELCI), http://www.elci.org/energy/EnergyAfrica.htm. No date.
34. "Implementation strategy to reduce environmental impact of energy related activities in Zimbabwe," 1997. Working Paper No. 5. Risø National Laboratory, Denmark. UNEP Collaborating Centre on Energy and Environment. http://www.uccee.org/Workpapers/wpaper5.htm.
35. "Lesotho at a Glance," World Bank, 2001. http://www.worldbank.org/data/countrydata/pdf.
36. "Lesotho-Utilities Sector Reform Project," World Bank, 2000. Project No. PID9217. http://www-wds.worldbank.org/cgi-bin/cqcgi/@production.env?
37. "Malawi at a Glance," World Bank, 2001. http://www.worldbank.org/data/countrydata/pdf.
38. "Malawi Data Profile," World Bank, 1999. http://devdata.worldbank.org.
39. "Malawi Economy," Countrywatch, 2000. http://www.countrywatch.com.
40. "Malawi Energy," Countrywatch, 2001. http://www.countrywatch.com.
41. "Malawi," Central Intelligence Agency, 2000. http://www.odci.gov/cia/publications/factbook/geos/mi.html.
42. "Malawi," Energy Information Administration, 1998. http://www.eia.doe.gov/emeu/world/country/cntry_MI.html.
43. "Malawi-Power VI," World Bank, 1995. http://www-wds.worldbank.org/cgibin/ cqcgi/@production.env? [2001]
44. "Mauritius at a Glance," World Bank, 2001. http://www.worldbank.org/data/countrydata/pdf.

45. "Mauritius Data Profile," World Bank, 1999. http://devdata.worldbank.org.
46. "Mauritius Economy," Countrywatch, 2000. http://www.countrywatch.com.
47. "Mauritius Energy," Countrywatch, 2000. http://www.countrywatch.com.
48. "Mauritius," Central Intelligence Agency, 2000. http://www.odci.gov/cia/publications/factbook/geos/mp.html.
49. "Mauritius," Energy Information Administration, 1998. http://www.eia.doe.gov/emeu/world/country/cntry_MP.html.
50. "Mozambique - Electricity Tariffs Study Document Type: ESMAP Paper," World Bank, 1995. http://wwwwds. worldbank.org/servlet/WDSServlet?pcont.
51. "Mozambique - The African Development Fund Approves a US $ 14 Million Loan to Finance the Rural Electrification Project (Electricity Iii Project) in Mozambique Electricity Tariffs Study Document Type: Esmap Paper," African Development Bank (ADB), 2001. http://www.afdb.org/knowledge/pressreleases2001/adf_55_2001e.htm.
52. "Mozambique at a Glance," World Bank, 2001. http://www.worldbank.org/data/countrydata/pdf.
53. "Mozambique Data Profile," World Bank, 1999. http://devdata.worldbank.org.
54. "Mozambique Economy," Countrywatch, 2000. http://www.countrywatch.com.
55. "Mozambique Energy," Countrywatch, 2000. http://www.countrywatch.com.
56. "Mozambique," Energy Information Administration, 1998.
57. "Mozambique: Electrical Power," MBendi, 2001. http://www.mbendi.co.za/indy/powr/af/mz/p0005.htm.
58. "Mozambique: Private Participation in Isolated Electrified Grids," Findings, Africa Region, No. 62, March 2001. World Bank.
59. "Mozambique-Energy Reform and Access," Project No. MZPE69183. World Bank, 2001.
60. "Namibia at a Glance," World Bank, 2001. http://www.worldbank.org/data/countrydata/pdf.
61. "Namibia Data Profile," World Bank, 1999. http://devdata.worldbank.org.
62. "Namibia Economy," Countrywatch, 2000. http://www.countrywatch.com.
63. "Namibia Energy," Countrywatch, 2000. http://www.countrywatch.com.
64. "Namibia," Central Intelligence Agency, 1999. http://www.odci.gov/cia/publications/factbook/geos/wa.html.
65. "Namibia," Energy Information Administration (EIA), 1998. http://www.eia.doe.gov/emeu/world/country/cntry_WA.html.
66. "Project Experience," 1999. http://www.edg.co.za/project%20experience%20and%20references.htm#_project_experience.
67. "Renewable Energies in South Africa," Part I and II. Department of Minerals and Energy, South Africa. http://www.dme.gov.za/energy/restrategy_part3.htm. No date.
68. "Renewable Energy and Integrated Resource Planning," K. Porter, Proceedings of Solar ‘92, Cocoa Beach, Florida, June 15-18, 1992, pp. 370-73.
69. "Rural Electrification in South Africa", Project Brief, Renewables for Sustainable Village Power (RSVP), NREL, 1998.
70. "Seychelles at a Glance," World Bank, 2001. http://www.worldbank.org/data/countrydata/pdf.

71. "Seychelles Data Profile," World Bank, 1999. http://devdata.worldbank.org.
72. "Seychelles Economy," Countrywatch, 2000. http://www.countrywatch.com.
73. "Seychelles Energy," Countrywatch, 2000. http://www.countrywatch.com.
74. "Seychelles," Central Intelligence Agency, 2000. http://www.odci.gov/cia/publications/factbook/geos/se.html.
75. "Seychelles," Energy Information Administration (EIA), 1998. http://www.eia.doe.gov/emeu/world/country/cntry_SE.html.
76. "South Africa at a Glance," World Bank, 2001. http://www.worldbank.org/data/countrydata/pdf.
77. "South Africa Data Profile," World Bank, 1999. http://devdata.worldbank.org.
78. "South Africa Economy," Countrywatch, 2000. http://www.countrywatch.com.
79. "South Africa Energy," Countrywatch, 2001. http://www.countrywatch.com.
80. "South Africa," Central Intelligence Agency, 2001. http://www.odci.gov/cia/publications/factbook/geos/sf.html.
81. "South Africa," Energy Information Administration, 2000. http://www.eia.doe.gov/emeu/cabs/safrica.html.
82. "Southern Africa Development Community," Energy Information Administration, 2001. http://www.eia.doe.gov/emeu/cabs/sadc.html.
83. "Swaziland at a Glance," World Bank, 2001. http://www.worldbank.org/data/countrydata/pdf.
84. "Swaziland: Household Energy Strategy Study," Report No. 198/97. Energy Sector Management Assistance Programme (ESMAP), 1997.
85. "Tanzania at a Glance," World Bank, 2001. http://www.worldbank.org/data/countrydata/pdf.
86. "Tanzania-Privatization and Private Sector Development," Project No. PID8083. World Bank, 1999.
87. "Technology Cooperation Agreement Pilot Project (TCAPP)," National Renewable Energy Laboratory (NREL), 2000. http://www.nrel.gov/tcapp/april_2000_tcapp_newsletter.html#UPCOMING TCAPP.
88. "Updates of Privatizations in South Africa and Africa," Investment Promotion Network, World Bank. http://www.ipanet.net/documents/WorldBank/databases/busmap/DF_collation.htm. No date.
89. "Utilities Sector Reform Project," Environmental Review. Main Report. Kingdom of Lesotho. Lesotho Electricity Corporation. World Bank, 2000. http://www-wds.worldbank.org/cgi-bin/cqcgi/@production.env?
90. "White Paper on the Energy Policy of the Republic of South Africa," Environment Liaison Centre International, Nairobi, Kenya (ELCI), 1998. http://www.elci.org/energy/WhitePaper.htm.
91. "Zambia at a Glance," World Bank, 2001. http://www.worldbank.org/data/countrydata/pdf.
92. "ZESA Seeks Greenlight for 30 Percent Tariff Hike," Financial Gazette (Harare) 10/12/2001. http://allafrica.com/stories/200110120479.htm.
93. "Zimbabwe at a Glance," World Bank, 2001. http://www.worldbank.org/data/countrydata/pdf.
94. "Zimbabwe-Power Sector Reform Program-APL Phase 1-Power Sector Reform Project." Project No. PID9354. World Bank, 2000

95. Abdullah, Dr. Haji Ahmad, Hassan, Dr. Ibrahim and Mohammad Awang Damit, 1998. Masterplan on Natural Gas Utilisation and Development in the ASEAN Region: ASEAN Energy Journal, Vol.1, No. 2, 1998, pp. 179-
96. Ahluwalia, Sanjeev S. 2000. Power Sector Reforms: A Review of the Process and an Evaluation of the Outcome. New Delhi: Prepared for National Council of Applied Economic Research.
97. Ahmad, Datuk Dr. Tajuddin Ali, 1997. Development of ASEAN Power Grid: ASEAN Energy Journal. Vol.1, No.3, 1998, pp. 57-68.
98. Alam, Manzoor, Jayant Sathaye, and Douglas Barnes. 1998. "Urban Household Energy Use in India: Efficiency and Policy Implications," Energy Policy, 26(No. 11, 1998) pp. 885-891.
99. Albouy, Y., Performance Monitoring for the Energy Sector, The World Bank, December 1999
100. Aqua-Media International Ltd., 1997. "The status of dams and hydropower development in 1997." Reproduced in The International Journal of Hydropower & Dams.
101. ASEAN Centre for Energy, 1999. ASEAN Plan of Action for Energy Cooperation 1999-2004. ASEAN Senior Officials Meeting on Energy (SOME) of the 17th ASEAN Ministers of Energy Meeting, 1-2 July 1999, Bangkok.
102. Asian Development Bank. 1999. Bank Policy Initiatives for the Energy Sector Asian Development Bank, February 1994 [cited July 1999].
103. Awerbuch 1996: Awerbuch, S., ed., "Valuing the Benefits of Renewables", Energy Policy, Special Issue, 24 (2), 1996.
104. Bacon, R.W. 1995. Privatization and Reform in the Global Electricity Supply Industry. Annual Review of Energy and Environment 20:119-143.
105. Balce, G.R., 1998. Pole-Vaulting Programme of the Energy Sector; Department of Energy, Metro Manila, Philippines, Unpublished.
106. Barnes, Douglas F. 1988. Electric Power for Rural Growth: How Electricity Affects Rural Life in Developing Countries. Rural Studies Series. Boulder, Colorado: Westview Press.
107. Barnes, Douglas F., and Jonathan Halpern, eds. 2000. The Role of Energy Subsidies. Edited by E. S. M. A. Program, Energy Services for the World's Poor. Washington D.C.: World Bank.
108. Barnes, Douglas F., Energy and Poverty: Strategies for Assisting the Rural Urban Poor, The World Bank, 2000.
109. Barnes, Douglas F., Willem M. Floor. Rural Energy in Developing Countries: A Challenge for Economic Development, The World Bank, 1996.
110. Barnes, Douglas, Kerry Krutilla and William Hyde. 1999. Urban Energy Transitions: Energy, Poverty and the Environment In the Developing World. World Bank Draft Manuscript.
111. Barua, Dipal C. "Grameen Shakti's Activity" Proceedings of World Renewable Energy Congress V, 20-25 September 1998 Florence, Italy, pp 2811-2816
112. Barua, Dipal C. Micro-Lending and Rural Economic Development: Lessons from Grameen Bank, Proceeding of "The Earth Technologies Forum" pp 65-74, International Climate Change Conference, 26-28 October'98.
113. Barua, Dipal C., "Energy's Role in rural Income Generation: The Grameen Strategy", Presented in the "Village Power Workshop, 1998" in Washington.

114. Besant-Jones, John, 1995. Attracting Finance for Hydroelectric Power. The World Bank Group, FPD Energy Note No. 3,
115. Bose, Sarmila, 1993. Money, Energy and Welfare. Delhi: Oxford University Press. New Delhi.
116. Bouille, Daniel, and Hilda Dubrovsky. 2000. Reform of the Electric Power Sector in Developing Countries: Case Study of Argentina. Buenos Aires: Institute of Energy Economics, Fundacion Bariloche.
117. Cabrera, R.E., 1992. Rural Electrification in the Philippines: In Rural Electrification Guidebook for Asia and the Pacific; Asian Institute of Technology, Bangkok, 1992, pp. 439-454.
118. Casten et al. 1997: S. Casten, M. Laser, J. Romero, B. Hirokawa, J. Braciak, R. Ross, R. G. Herst, and L. Lynd: "Costs and features of advanced biomass ethanol/electricity generation technology". Poster paper presented at Making a Business from Biomass in Energy, Environment, Chemicals, Fibers, and Materials, Third Biomass Conference of the Americas, Montreal, Canada, 24-29 August 1997.
119. Cavallo 1995: A. Cavallo, "High capacity factor wind energy systems", Journal of Solar Engineering, 117, 1995, 137-143.
120. Celelski, E., Enabling Equitable Access to Rural Electrification: Current Thinking and major Activities in Energy, Poverty and Gender, The World Bank, January 2000.
121. Chella Rajan, Sudhir. 1998. The Role of Independent Democratic Regulation in the Power Sector: Some Principles. Paper read at 12th Annual Conference of the Electrical Power Supply Industry Workshop, November 2-5, at Pattaya.
122. Cohen 1997: J. Cohen, Summary of Large HAWTs in Windfarms Technology Characterization. (Princeton Economic Research, Inc., Rockville, Md.) Prepared for the NREL under Subcontract No. AAT-6- 15292-01, June 1997
123. Covarrubias, Alvaro J., and Kilian Reiche, eds. 2000. A Case Study on Exclusive Concessions for Rural Off-Grid Service in Argentina. Edited by E. S. M. A. Program, Energy Services for the World's Poor. Washington D.C.: World Bank.
124. De Laquil et al. 1993: P. De Laquil, D. Kearney, M. Geyer, and R. Diver, "Solar-thermal electric technology", in Renewable Energy: Sources for Fuels and Electricity, Johansson, T.B., H. Kelly, A.K.N. Reddy, and R.H. Williams (eds.), (Washington, DC: Island Press, 1993)
125. Department of Energy, 1998. Philippine Energy Plan 1999-2008; Energy Planning and Monitoring Bureau, DOE, Metro Manila, Philippines.
126. Department of Energy, 1999. Energy Resources for the Alleviation of Poverty (ERAP) Programme Framework; EUMB, DOE, Metro Manila, Philippines, Unpublished draft.
127. Department of Energy, 1999. Guide to Minihydro power Development in the Philippines; Minihydro Division, EUMB, DOE, Metro Manila, Philippines.
128. Dewan A. H. Alamgir, "Application of Photovoltaics System as an Alternative Sources of Electricity for Rural Areas in Bangladesh": Prospects and Challenges, Proceedings of IEB Conference March '99, pp 94-100.
129. Dewan A. H. Alamgir, "Utilisation of Wind Energy of Coastal Areas of Bangladesh by Using Hybrid Energy System for the Coastal Regions of Bangladesh", Proceedings of NSURAESD'98, pp 107-126.

130. DGEED, Indonesia. Statistic and Information on Electricity and Energy, 1999
131. Domdom, A. C., Abiad, V. G., Paimio H.S., Rural Electrification Benefit Assessment Study (Draft), The World Bank, September 1999.
132. Domdom, Aleta, Virginia Abiad, and Harry Pasimio, 2000. “Rural Electrification Benefit Assessment Study: The Case of the Philippines,” ESMAP Draft Report, World Bank, Washington, DC.
133. Duff, Winston, and O'Gallagher, "Cooling of Commercial Buildings with ICPC Solar Collectors", Solar Engineering, Vol. 2 ASME, 1995.
134. Elauria, J., 1998. Status, Plans and Opportunities of New and Renewable Energy in the Philippines: In Proceedings of the Conference and Roundtable Discussion/Workshop on New and Renewable Energy Resources: Pole Vaulting Towards Sustainable Energy Development; Department of Energy, 1998, Attachment B, Unpublished.
135. Electricity Regulatory Journal (April, June, October, December 2000; March, April, May, June 2001). National Electricity Regulator (NER, South Africa).
136. Ellegard, Anders, and Mattias Nordstrom, 2001. "Rural Energy Service Companies-Experiences from Zambia." Stockholm Environment Institute (SEI). http://www.sei.se/energy/pvesco/PV%20ESCOs%20phase%20I%20final %20report.pdf.
137. Electrical Safety Code – Code of Practice, Zambia Bureau of Standards, DZS 418: Part1.
138. Energy survey for SPV power plants by SESI (Eastern Region Chapter)
139. Energy for Rural Development in Zambia, Proceedings of a National Policy Seminar, Sida/SAREC and AFREPREN/FWD, October 2000.
140. ESMAP, 1990. “Indonesia: Urban Household Energy Strategy Study — Main Report,” ESMAP Report No. 107A/90, World Bank.
141. ESMAP, Energy Services for the Poor: Energy and Development Report 2000, The World Bank, 2000.
142. ESMAP. 1991. “Bolivia Prefeasibility Evaluation Rural Electrification & Demand Assessment,” Energy Management Assistance Program, World Bank, Washington, DC.
143. ESMAP. 1994. Ecuador Energy Pricing, Poverty & Social Mitigation, Energy Management Assistance Program, World Bank, Washington, DC.
144. ESMAP. 1999. India: Household Energy Strategies for Urban India: The Case of Hyderabad. Joint UNDP/ESMAP Report 214/99, World Bank, Washington, DC.
145. ESMAP. 1999. Lao PDR: Institutional Development for Off-Grid Electrification, Joint UNDP/ESMAP Report 214/99, World Bank, Washington, DC.
146. ETSU, United Kingdom Department of Trade and Industry, RE Reviews, April 1994, February 1995), Renewable Energy Bulletin, December 1995.
147. Export Strategy for Renewables An Interview with Muhammed Yunus, the founder of the Grameen Bank in Bangladesh
148. Facts of Zambia, CIA World Factbook 2002, World Development Indicators Database, EIU Country Profiles, Estimated figures, CIA 2002
149. Financing Large-Scale Increases in Pv Production Capacity Through Innovative Risk-Management Structures and Contracts by Eric Ingersoll, Robert Dimatteo, and Romana A. Vysatova http://www.repp.org/article

150. Fitzgerald, K., D. Barnes, and G. McGranahan. 1990. “Interfuel Substitution and changes in the Way Households Use Energy: The Case of Cooking and Lighting Behavior in Urban Java.” Industry and Energy Department Working Paper, Energy Series Paper No. 29, World Bank, Washington, D.C.
151. Foley, G. 1992. Alternative Institutional Approaches to Rural Electrification Guidebook for Asia and the Pacific; Asian Institute of Technology, Bangkok, 1992, pp. 71-90.
152. Food and Agriculture Organization, 1997. FAOSTAT Statistics Database. On the internet at:. Rome, Italy: FAO.
153. Forest et al. 1997: H. Forest and G. Braun, "Renewable energies: are we on track?" Paper presented at the 1997 Environment Northern Seas Conference, Stavanger, Norway, 28 August 1997.
154. Geche, John, and Julia Irvine, 1996. "Photovoltaic Lighting in Rural Botswana: A Pilot Project," Stockholm Environment Institute (SEI), Renewable Energy for Development, Vol. 9, No. 2, Sep. 1996. http://www.sei.se/red/red9609e.html.
155. Gipe, Paul, Wind Power Renewable Energy for the 1990s and Beyond, Chelsea Green Publishing Company, 1993.
156. Goldemberg, J., Johansson, T.B., edited, Energy as an Instrument for Socio-Economic Development, UNDP, 1995.
157. Government Procurement to Expand Pv Markets by Joel Stronberg And Virinder Singh
158. Grubb et al. 1993: M.J. Grubb and N.I. Meyer: "Wind energy: resources, systems, and regional strategies" in Renewable Energy: Sources for Fuels and Electricity, Johansson, T.B., H. Kelly, A.K.N. Reddy, and R.H. Williams (eds.) (Washington, DC: Island Press, 1993).
159. G.S. Hamutwe, Solar Power in Namibia, February, 1999
160. Heruela, C.S., 1993, Rural Energy Systems in the Philippines: In Rural Energy Systems in the Asia-Pacific; Asian and Pacific Development Centre, Kuala Lumpur, 1993, pp.451-506.
161. Hills, O'Keefe and Snape, The Future of Energy Use, Earthscan, 1995
162. http://www.eia.doe.gov/emeu/world/country/cntry_MZ.html.
163. Hybrid Systems for Village Power Development in the U.S. Larry Flowers, National Renewable Energy Laboratory
164. Iwayemi, Akin. "Energy Sector Development in Africa," http://www.elci.org/energy/Energization.htm. No date.
165. Issues and Options for Rural Electrification in Zambia, CORE International, Inc., Report to USAID, 2002.
166. Jennifer L. Edwards*, Chris Marnay, Emily Bartholomew, Boubékeur Ouaglal, Afzal S. Siddiqui, and Kristina S. H. LaCommare, “Assessment of µGrid Distributed Energy Resource Potential Using DER-CAM and GIS”, Ernest Orlando Lawrence Berkeley National Laboratory, January 2002
167. J. L. Stone, H. S. Ullal, and E.V.R. Sastry, “The Indo- U.S. Cooperative Photovoltaic Project,” 26th IEEE Photovoltaics Specialists Conference, Sept.30-Oct.3, 1997, Anaheim, CA, pp. 1273-1275.
168. J.L. Stone and H. S. Ulal, “PV Opportunities in India,” 13 NREL Photovoltaics Program Review, Lakewood, CO, 1995, pp. 275-280, AIP Conference Proceedings 353.

169. J.L. Stone and H.S. Ullal, “The Ramakrishna Mission PV Project — a Cooperation between India and the United States,” NREL/SNL Photovoltaics Program Review, Proceedings of the 14 Conference—A Joint Meeting, the Lakewood, CO, 1966, pp. 521-527, AIP Conference Proceedings 394.
170. Jadresic, Alejandro, 2000. “Subsidies for Rural Electrification in Chile,” Draft Background paper for Energy and Poverty 2000, World Bank, Washington, DC.
171. Johanssen, Kelly Reddy, & Williams, Renewable Energy, Sources for Fuels and Electricity, Earthscan & Island Press, 1993.
172. Johansson et al. 1993: T.B. Johansson, H. Kelly, A.K.N. Reddy, and R.H. Williams, 1993: "Renewable fuels and electricity for a growing world economy: defining and achieving the potential" in: Renewable Energy - Sources for Fuel and Electricity, T.B. Johansson, H. Kelly, A.K.N. Reddy, and R.H. Williams (eds.), (Washington, DC: Island Press, 1993).
173. Karekezi, Stephen. "Renewable energy technologies as an option for a low-carbon energy future for developing countries: case examples from Eastern and Southern Africa," http://www.uccee.org/CopenhagenConf/karekezi.htm. No date.
174. Kelly et al. 1993: H. Kelly and C. Weinberg, 1993: "Utility strategies for using renewables", in Renewable Energy - Sources for Fuel and Electricity, Johansson, T.B., H. Kelly, A.K.N. Reddy, and R.H. Williams (eds.), (Washington, DC: Island Press, 1993).
175. Kozloff, Keith. 1998. Electricity Sector Reform In Developing Countries: Implications for Renewable Energy. Washington D.C.: Renewable Energy Power Project.
176. Laing, Cathy A. and Glynne Rosselli, 1998. "Energization: A Collaborative Application of Conventional Energy Resources For Energy Upliftment In Rural Communities,"
177. Laws Of The Republic Of Zambia, Volume 16, 1995 Edition (Revised)
178. Leeper, J. D., and Barich, J. T., "Technology for Distributed Generation in a Global Market Place", American Power Conference, Chicago, April 14- 16, 1998.
179. Liebenthal A S, Mathur S, Wade H. 1994. Solar Energy: Lessons from the Pacific Islands Experience. World Bank Technical Paper No. 224, Energy Series, Washington, D C: The World Bank.
180. Lovejoy D R. 1991. Experience with Village PV Systems in Pakistan. pp 1126–1129. 10th European Solar Energy Conference, Lisbon, Portugal, 8–12 April 1991.
181. Maduna, Dr. P.M., and S. Shabangu, 1998. "White Paper on the Energy Policy of the Republic of South Africa." Environment Liaison Centre International, Nairobi, Kenya (ELCI). http://www.elci.org/energy/WhitePaper.htm.
182. Marnay et al. 1997: C. Marnay, R.C. Richey, S.A. Mahler, and R.J. Markel (Energy Analysis Program, Lawrence Berkeley National Laboratory), 1997: "Estimating the environmental and economic effects of widespread residential PV adoption using GIS and NEMS", Paper presented at the 1997 ASES meeting, Washington, DC, May 1997.

183. Martens, J.W., T. de Lange, J. Cloin, S. Szewczuk, R. Morris, and J. Zak. "Accelerating the Market Penetration of Renewable Energy Technologies in South Africa." http://www.uccee.org/RETSouthAfrica. No date.
184. Martens, J.W., T. de Lange, J. Cloin, S. Szewczuk, R. Morris, and J. Zak. "Accelerating the Market Penetration of Renewable Energy Technologies in South Africa-Action Plan Summary." http://www.uccee.org/RETSouthAfrica. No date.
185. Mason M. 1990. Rural Electrification: A review of World Bank and USAID financed projects, draft background paper. April 1990.
186. Mintzer, Irving, Miller, Alan, Serchuk, Adam, The Environmental Imperative, Renewable Energy Policy Project Solstice, at http://solstice.crest.org/renewables/repp
187. Mkhwanazi, Xolani H. "Address to the National Power Forum 2000 by Xolani H. Mkhwanazi, Chief Executive of the National Electricity Regulator (NER), At Midland on 8 February 2000. http://www.ner.org.za/speeches/08022000NPF.htm.
188. Mock et al. (1998): J.E. Mock, J.W. Tester, and P.M. Wright, "Geothermal Energy From the Earth: Its Potential Impacts as an Environmentally Sustainable Resource," Annual Reviews of Energy and the Environment 22: 305-356 AR-039-10 (1998).
189. Modeling Renewable Energy Resources in Integrated Resource Planning, D. Logan, C. Neil, and A. Taylor, RCG Hagler, Bailly, Inc., 1994.
190. Models and Methods for Rural Electric Service, Daniel B. Waddle, NRECA International, Ltd., August, 1997
191. National Power Corporation, 1998. Power Development Programme (1998-2010); Corporate Planning Group; NPC, Diliman Quezon City, Philippines, Unpublished.
192. Nieuwenhout, F. P. van der Rijt, E. Wiggelinkhuizen, “Rural Lighting Services: A Comparison of Lamps for Domestic Lighting in Developing Countries,” Netherlands Energy Research Foundation, Netherlands.
193. Non-Grid Electricity Regulation: Towards Sustainable Rural Development, EU Synergy Workshop CSIR – Pretoria, NREL, February 2001.
194. O'Leary, Donal T., Jean-Pierre Charpentier, and Dianne Minogue. "Promoting Regional Trade-The Southern African Power Pool," Private Sector, Note No. 145, June 1998.
195. Operation Evaluation Department (OED), Rural Electrification: A Hard Look at Costs and Benefits, Precis No. 90, The World Bank, May 1995.
196. Philipson, L., and Willis, H. L., Understanding Electric Utilities and Deregulation, Marcel Dekker, 1988.
197. Policies to Support a Distributed Energy System by Thomas J. Starrs and Howard J. Wenger
198. Policy on Private Participation in the Power Sector, the Gazette of India, Extraordinary part I - section 1, published by authority, No. 237, New Delhi, Tuesday, October 22, 1991/Asvina 30, 1913, Ministry of Power & Non-conventional Energy Sources, [Department of Power], New Delhi, the 22nd October, 1991

199. Porter, James, 1994. "Manyana Pilot Project Evaluation," Renewable Energy for African Development, Baltimore, MD. http://fermi.udw.ac.za/renew/manyana/manyana.html.
200. Ramani, K. V, et. al. Rural Energy Systems in Asia-Pacific: APDC, Kuala Lumpur, Malaysia, 1993.
201. Ramani, K.V. 1993. Rural Energy Systems in the Asia-Pacific: Regional Overview and Country Profiles; Asian and Pacific Development Centre, Pesiaran Duta, Kuala Lumpur, Malaysia, p.17.
202. Reddy, A.K.N., Williams, R. H, Johansson, T.B., Energy After Rio: Prospects and Challenges, 1997.
203. Renewable Energy Technologies: A Review of the Status and Costs of Selected Technologies. Kulsum Ahmed. World Bank Technical Paper 240.
204. Revisiting Solar Power's Past by Charles Smith in Tech Review, July 1995.
205. Rinehart et al. 1997: B.N. Rinehart, J.E. Francfort, G.L. Sommers, G.F. Cada, and M.J. Sale, DOE Hydropower Program Biennial Report, U.S. Department of Energy, Idaho Operations Office, 1996-1997, (1997).
206. Rukato, Hesphina. 2001. "Gender and Energy in the South: A Perspective from Southern Africa," http://www.earthsummit2002.org/workshop/Gender%20&%20Energy%20S%20HR.txt.
207. Rural Electric Cooperatives IRP Survey, C. Garrick, National Renewable Energy Laboratory, 1995.
208. SESI (India) journal, vol. 8.Number -1,1998.Socio-economic evaluation of solar lanterns by Joysree Roy.
209. Shanker, A. and G.G. Krause, 1992. Decentralized Small-Scale Power Systems: In Rural Electrification Guidebook for Asia and the Pacific; Asian Institute of Technology, Bangkok, 1992, pp.243-300.
210. Smith, Kirk, 1987. Biofuels, Air Pollution and Health: A Global Review. New York: Plenum Press.
211. Solar Energy: Lessons from the Pacific Island Experience. Andres Liebenthal, Subodh Mathur, and Herbert Wade. World Bank Technical Paper 244.
212. Solar: Financing Household Solar Energy in the Developing World Michael F. Northrop, Peter W. Riggs, Frances A. Raymond A Report based on a Workshop at the Pocantico Conference Center of the Rockefeller Brothers Fund, October 11-13, 1995.
213. Specifications For The Use Of Renewable Energies In Rural Decentralized Electrification, Internacional Electrotechnical Commission, IEC/PAS 62111, 1999
214. State of Environment in Zambia 2000, Environmental Council of Zambia, Lusaka-Zambia, ECZ 2001.
215. Submission and Evaluation of Proposals for Private Power Generation Projects in Developing Countries. Peter A. Cordukes, editor. World Bank Discussion Paper No. 250.
216. Sustainable Development, Asian and Pacific Perspectives, Asian Development Bank, 1999.
217. Tania P. Urmee, "Promotions of Renewable Energy Sources in Bangladesh: Lessons from Grameen Shakti", Proceedings of world Sustainable Energy Day, Austria, March 1999, pp 93-98.

218. TERI. 1993 A Socio-economic Impact Assessment Study of Urjagram Projects - Interim Report. GR3402. New Delhi: TERI. 164 pp.
219. TERI. 1994b. Performance Evaluation of SPV Power Plants in UP, Final Report (Phase II). GR4461. New Delhi: TERI. 56 pp.
220. Tester et al. (1989): J.W. Tester, D.W. Brown, and R.M. Potter, "Hot Dry Rock Geothermal Energy: A New Energy Agenda for the 21st Century," Los Alamos National Laboratory Report, LA-11514-MS, July 1989.
221. The Case for Solar Energy Investments. Dennis Anderson and Khulsum Ahmed World Bank Technical Paper No. 279.
222. The Changing Structure of the Electric Power Industry, 1970-1991, March 1993, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, U.S. Department of Energy, Washington, DC 20585
223. The Cost-Effectiveness of GEF Projects. Dennis Anderson and Robert H. Williams. Global Environment Facility Working Paper 6.
224. The Environmental Protection and Pollution Control Act, 1990, The Laws of Zambia, Cap 204
225. The Financing of Hydropower, Irrigation and Water Supply Infrastructure in Developing Countries, a background paper for the UN Commission on Sustainable Development, January 1998, by John Briscoe, Senior Water Advisor, World Bank
226. The Public Benefits Agenda in Power Sector Reform, submitted to Energy for Sustainable Development, January 31, 2001, by Navroz K. Dubash, Senior Associate, World Resources Institute, 10 G St. NE, Suite 800, Washington DC 20009
227. The Rio Declaration on Environment and Development, Agenda 21 Sustainable Development Principles, UNCED, June 1992.
228. The Stockholm Environment Institute, Energy Interventions and Poverty Alleviation: Strengthening the Linkages, 1999.
229. The Stockholm Environment Institute, Energy Interventions and Poverty Alleviation: Strengthening the Linkages, 1999.
230. Trembath, Barry, 1997. Constraints to Hydropower Development in a Privatizing Sector. Paper presented at the World Bank's Energy Week, Washington DC, March 13-14, 1997.
231. Tuntivate, Voravate and Douglas F. Barnes, "Thailand’s Approach to Rural Electrification: How Was It Successful," The World Bank, Washington DC. Draft, 1997.
232. Tuntivate, Voravate, Douglas F. Barnes, and Susan Bogach, Assessing Markets for Renewable Energy in Rural Areas of Northwestern China, ESMAP Technical Paper No. 3, World Bank, Washington, DC.
233. Ulfsby, Oyvind, 1997. Project Financing of Hydropower Projects in Developing Countries: Some Issues Worth Discussion. Paper presented at the World Bank's Energy Week, Washington DC, March 13-14, 1997.
234. UNDP, World Energy Assessment, New York, UNDP, 2000
235. Urja Bharati - Special issue on solar energy 15(1).
236. Van der Plas R J. 1997. Solar Lanterns: Results of marketing tests in the rural areas of Kenya and Niger. Journal of Energy in South Africa April 1997.

237. Van der Plas, Robert, and A.B. de Graaff. 1988. “A Comparison of Lamps for Domestic Lighting in Developing Countries.” Energy Series Paper 6. Washington, D.C.: World Bank, Industry and Energy Department.
238. Wamukonya, Njeri (ed.), 2001. "Proceedings of the African High-level Regional Meeting on Energy and Sustainable Development for the Ninth Session of the Commission on Sustainable Development," United Nations Environment Programme (UNEP).
239. Wan, Yihn-huei, Parsons, Brian, NREL Factors Relevant to Utility Integration of Intermittent Renewable Technologies, United States Government, NREL/TP463-4953, August 1993.
240. WEC 1994: World Energy Council, New Renewable Energy Resources) A Guide to the Future, (London, UK: Kogan Page, 1994).
241. Willis, H. L., and Scott, W. G., Distributed Power Generation, Marcel Dekker, 2000.
242. World Bank, Rural Energy and Development: Improving Energy Supplies for Two Billion People, Development in Practice Series, The World Bank, 1996.
243. World Bank. Evaluation Of Photovoltaic Household Electrification Programs: Indonesia, Consultants Report, Asia Alternative Energy Unit. Washington, D C: The World Bank.
244. World Competitiveness Report 1997, World Economic Forum
245. Wright et al. (1997): P.M. Wright, T. Sparks, D. Schochet, et al., Geothermal Energy, briefing document for the PCAST Renewable Energy Task Force (Washington, DC: 30 June 1997).
246. Yeager, Kurt, 1997. New Technologies for Power. Paper presented at the World Bank's Energy Week, Washington DC, March 13-14, 1997.
247. Yturregui, L.P., Coping with a Lack of Electricity in Marginal Urban Areas, ENEGIA News,

SELECTED WEB SITES

World Bank http://www.worldbank.org
International Monetary Fund http://www.imf.org
Food and Agriculture Organization http://www.fao.org/
United Nations http://www.un.org
Asian Development Bank http://www.adb.org
National Rural Energy http://www.nreca.org
Cooperative Association
Public Utilities Reports, Inc. http://www.pur.com
Oak Ridge National Laboratory http://www.ornl.gov
National Renewable Energy http://www.nrel.org
Laboratory
National Technical Information http://www.ntis.gov
Service (NTIS)
American Solar Energy Society http://www.ases.org
International Centre for http://www.icimod.org.np
Integrated Mountain Development
China http://www.pnl.gov/china/

Thailand http://www.dedp.go.th/,
http://berc.dedp.go.th/NRSE/
http://www.nepo.go.th/
http://www.egat.or.th/
http://www.pea.or.th/
Bangladesh http://www.bangladeshgov.org
http://bd-pdb.org
http://www.grameen.net
India http://www.nic.in
http://rec.nic.in
http://www.teriin.org

Other websites on Energy:
http://www.repp.org
http://www.ourplanet.com
http:// www.eia.doe.gov
http://www.eurosolar.org/
http://www.futureenergies.com/
http:// www.cei.org
http:// www.udel.edu
http://www.rsvp.nrel.gov
http://www.web.net/newenergy/links.html
http://solstice.crest.org/renewables/re-kiosk/index.shtml
http://www.energy.ca.gov/energy/education/eduhome.html
http://www.itc.nl/ha2/energy/links/biomass.html
http://www.itc.nl/ha2/energy/links/wind.html
http://www.itc.nl/ha2/energy/links/solar.html
http://www.itc.nl/ha2/energy/links/hydro.html
http://www.itc.nl/ha2/energy/links/other.html
http://www.solartoday.org/
http://solarcentury.co.uk
http://www.adal.com
http://www.worldbank.org/html/fpd/energy/energynotes
http://www.repp.org/article
http://apps.fao.org
http://www.web.net/newenergy/links.html
http://solstice.crest.org/renewables/re-kiosk/index.shtml
http://www.energy.ca.gov/energy/education/eduhome.html
http://www.itc.nl/ha2/energy/links/biomass.html
http://www.itc.nl/ha2/energy/links/wind.html
http://www.itc.nl/ha2/energy/links/solar.html
http://www.itc.nl/ha2/energy/links/hydro.html
http://www.itc.nl/ha2/energy/links/other.html
http://www.solartoday.org/
http://solarcentury.co.uk
http://www.adal.com
http://www.worldbank.org/html/fpd/energy/energynotes
http://www.repp.org/article
http://apps.fao.org
http://www.wired.com/news/technology/0,1282,66694,00.html#121
http://www.teriin.org/renew/tech/hydro/about.htm
http://alt-e.blogspot.com/2005/02/alternative-energy-zambia-solar-power.html

http://www.dis.anl.gov/CEEESA/about_programs_power_systems.html
http://microhydropower.net/download/books.php
http://www.fews.net/centers/?f=zm
http://www.awea.org/faq/tutorial/wwt_basics.html
http://data.geocomm.com/catalog/ZA/
http://www.zamsif.org.zm/